ELEMENTARY PHYSIOLOGY

BHATIA AND SURI

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PREFACE

THIS book has been mainly written to meet the requirements of students in High and Higher Secondary Schools, but it can also serve as an explicit guide to anyone desiring to acquire an elementary knowledge of Physiology. A companion volume on Elementary Hygiene is also available for the same purpose.

An elementary knowledge of the salient principles of Physiology will be found advantageous for the proper understanding of the elements of Hygiene. It is, therefore, recommended that the study of Elementary Physiology should precede that of Elementary Hygiene. To make the book interesting and instructive to the reader, an attempt has been made, in as lucid a manner as possible, to correlate important topics from other sciences that govern the function and working of the human body. This will enable the reader to acquire a wide outlook and create in him a multi-purpose interest.

The book is purposely not crowded with technical terms and contains only those that are essential for the purpose of acquiring an elementary knowledge of the subject. The latest revisions and editions have made this book quite up to date and it covers the entire course on the subjects as prescribed in High and Higher Secondary Schools.

Questions have been supplied at the end of each chapter to facilitate proper assimilation and revision of the matter studied before proceeding with the next chapter.

Thanks are due to Dr. Lal Chand Khanna, ex-Professor of Physiology, K.E. Medical College, Lahore and Lady Hardinge Medical College, New Delhi, for going through the book and making useful suggestions.

PREFACE TO THE FIFTEENTH EDITION

THE book has been thoroughly revised and brought to the standard of Higher Secondary School Examinations of various States.

P.N.S.

CONTENTS

CHAP. PAGE

I. THE GENERAL BUILD OF THE BODY .. 1
II. THE COMPOSITION OF THE BODY .. 13
III. THE SKELETON 26
IV. THE SKELETON (*contd.*) 31
V. THE SKELETON (*contd.*) 36
VI. JOINTS, MUSCLES AND MOVEMENTS .. 42
VII. FOOD AND ITS COMPOSITION : VITAMINS 51
VIII. THE PROCESSES OF DIGESTION .. 59
IX. THE LIVER, PANCREAS AND SPLEEN .. 73
X. THE DUCTLESS OR ENDOCRINE GLANDS HORMONES 77
XI. THE BLOOD 80
XII. THE CIRCULATION OF BLOOD : BLOOD PRESSURE 85
XIII. BLOOD-VESSELS: LYMPHATICS .. 98
XIV. RESPIRATION 103
XV. THE KIDNEYS AND THE EXCRETION OF URINE 114
XVI. THE SKIN AND THE EXCRETION OF SWEAT BODILY HEAT 120
XVII. THE NERVOUS SYSTEM 127
XVIII. THE NERVOUS SYSTEM (*contd.*) — 141
XIX. THE SPECIAL SENSES: TOUCH, TASTE AND SMELL 146
XX. THE EYE AND VISION 152
XXI. THE EAR AND HEARING 164
XXII. THE LARYNX AND VOICE 170

CHAPTER 1

THE GENERAL BUILD OF THE BODY

Physiology.—The universe is inhabited by three great kingdoms of living organisms in the biosphere (*Bios*-life):

(1) Animal Kingdom
(2) Plant Kingdom, and
(3) Microbial Kingdom.

Every living being starts its existence as a tiny object, feeds and grows, carries on certain other life processes and sooner or later dies, leaving children behind. How all this is taking place is an interesting study. We should all take a great interest in the working of our body. If a child has a clock-work toy, he wishes to learn all about it, and left to himself, he soon breaks it to pieces to satisfy his curiosity. No one will entrust his watch to a watch repairer who does not fully understand its construction, and no sensible person will permit another to fly an air-ship or drive a motor car or a steam-engine, unless the latter has learnt a good deal about the construction and working of the machine. Every one of us is in charge of a delicate and intricate machine, the human body, and it is our duty to learn how it works, and how it can be looked after properly.

Physiology deals with the function of the body, the phenomena of life and classifications of these phenomena. The word 'physiology' is derived from the Greek words *phusis*, nature, and *logos*, a discourse, but the term is applied now only to the study of the *functions* of living beings. Before you can understand anything of the functions of the body, you must learn something about its *structure*. The science of *Anatomy* deals with the structure of the different parts of the body. We can learn anatomy best by cutting up or dissecting a dead body and its parts. The structure of a higher animal, like a rabbit or a sheep, closely resembles that of the human body and even in an elementary class it will be a distinct advantage if the students examine carefully the parts in a dissection of one of these animals. In this little book the structure of the different parts of the body will be described at the same time as their functions or actions and uses are discussed. The sister science of *Hygiene* tells us how we can keep ourselves healthy and how the health of the entire community can be promoted. It is best to study Physiology and Hygiene side by side as the former makes a rational basis for the latter.

Parts of the Body.—The human body consists of the head, neck, trunk and limbs. The *head* includes the face and a bony box or cranium which encloses the brain. The *neck* connects the head with the trunk and comprises various structures passing from one to the other, such as the food-pipe, windpipe, etc. The *trunk* encloses a large cavity which is divided internally into two parts by a fleshy partition called the *diaphragm*. The upper portion of the trunk is called the thorax or chest and contains the heart, the lungs, foodpipe, etc. The lower portion of the trunk is known as the *abdomen* or belly and contains the stomach, intestines, liver, pancreas, spleen, kidneys, etc. There are two pairs of *limbs*, viz. *arms* or upper extremities and the *legs* or lower extremities.

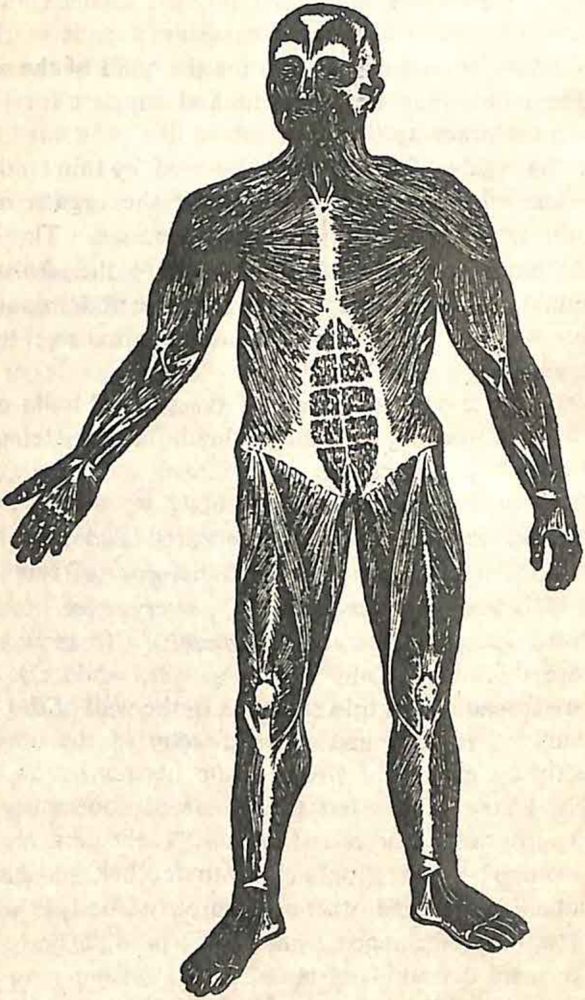
Organs and their functions.—Both outside and inside the body there are many distinct parts, each doing its special kind of work. Each part is called an *organ* and its special work is described as its *function*. Thus the hand is the organ for grasping, the eye is the organ of sight, the tongue, the organ of taste, the stomach, an organ of digestion, and so forth. All the organs work together for the benefit of the whole. In all higher animals, including man, the various important functions of life, such as digestion, respiration, and excretion are carried on by sets of closely related organs constituting several systems. Thus the digestive system consists of the mouth, gullet or foodpipe, stomach, intestines, liver, pancreas, etc., and all these are organs of digestion, working together in unison for the good of the whole body, and obtaining nourishment and support for themselves from other systems.

All the organs of the body are covered by thin epithelial membrane which keeps the surface of the organs moist. Thus the heart is covered by the *pericardium*. The lungs and the inner surface of the chest wall by the *pleura*, the abdominal organs and the inner side of the abdominal wall by the *peritoneum* and the brain and the spinal cord by the *meninges*.

A good idea can be formed of the general build of the body and its working by naming the different systems and the work they undertake.

Muscular System.—The whole body is covered by the *skin* which, besides protecting the parts inside, is an important organ of excretion and of the sense of touch. If the skin is removed, underlying it, everywhere, are seen numerous fleshy bands known as *muscles*. In some places they are thick and fleshy as in the calf, while elsewhere they are spread out in thin sheets as in the wall of the belly. The muscles are attached either directly to the bones or indirectly by means of strong white fibrous bands called *tendons*. Every muscle has the power of contraction and thus may become shorter and thicker. As the ends are fixed to bones one bone is brought closer to another, and a movement of a limb or some other portion of the body is produced. The muscles also give a graceful form to the body.

There are two kinds of muscles, viz. *voluntary* or those which are under the control of the will and *involuntary* or those which are not. The muscles of the limbs, trunk and the face (all seen in Fig. 1) are examples of voluntary muscles and muscles in the wall of the stomach, intestines or the heart are of the involuntary kind.



I ig. 1—*The Superficial Muscles of the Body, viewed from the front.*

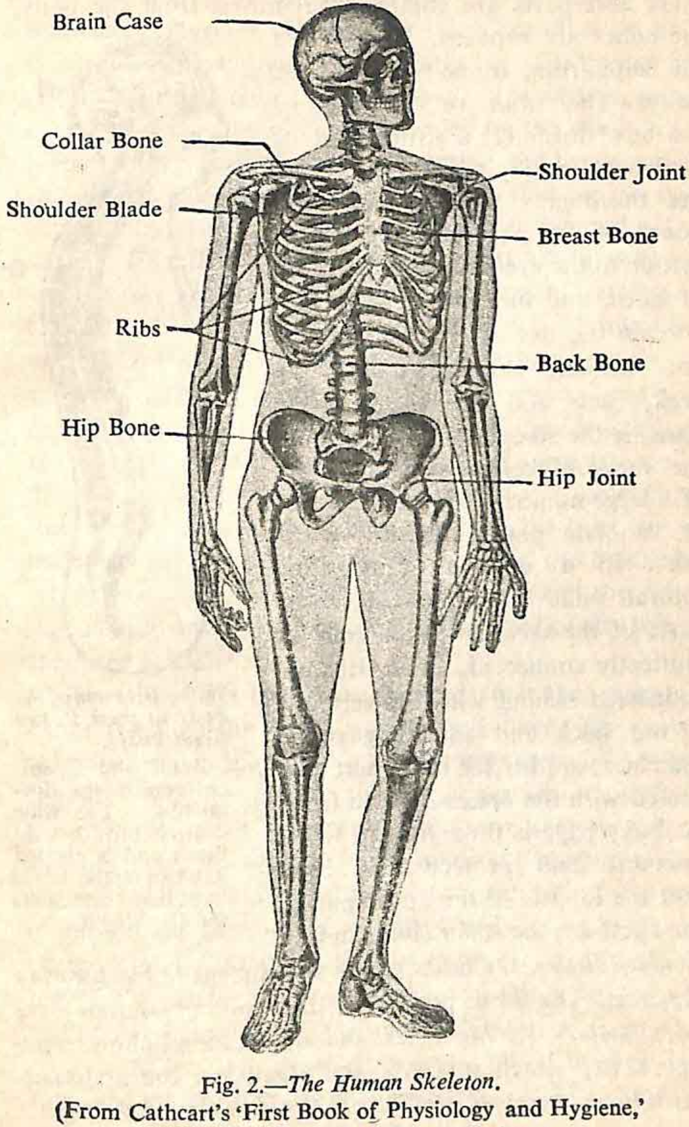


Fig. 2.—*The Human Skeleton.*
(From Cathcart's 'First Book of Physiology and Hygiene,'
Macmillan & Co. Ltd. By permission.)

The Skeleton or the Bony System.—If the muscles and other soft parts are completely removed from the body, the bones are exposed. These form the supporting frame-work of the body. The *skull* or the bones of the head form (1) a strong case or brainbox, inside which the brain lies thoroughly protected, and (2) bones of the face which give protection to the eye-balls and the organ of smell, and the jaw bones which contain the teeth. In the middle line behind, running down the neck, back and the region of the loins, is the so-called 'back-bone' or the *vertebral column* which consists of a large number of separate bones or vertebræ placed one above the other in a column. This is the central pillar to which all other parts of the skeleton are directly or indirectly connected. The ribs are connected behind with the vertebræ of the back and extending round the chest, are for the most part connected with the *breast-bone* in front. A bony cage is thus formed which contains and protects the heart and the lungs. At the upper part of the chest are the *collar bones* and the *shoulder blades*, the latter giving attachment to the *bones of the arms*. The lower portion of the vertebral column gives attachment to the *hip-bones*, and thus forms a hollow basin-like cavity which supports the organs of the abdomen. Each hip-bone gives attachment to the *bones of the leg*.

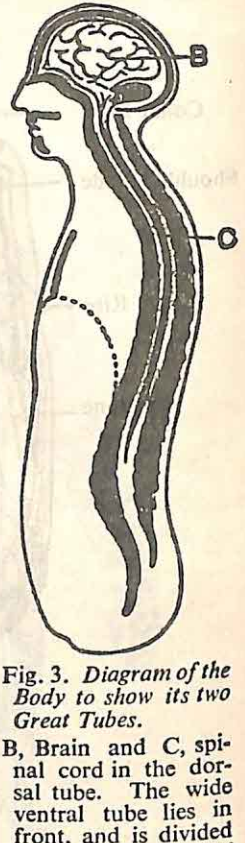


Fig. 3. *Diagram of the Body to show its two Great Tubes.*

B, Brain and C, spinal cord in the dorsal tube. The wide ventral tube lies in front, and is divided into two by the dotted line that represents the diaphragm.

Down the vertebral column runs a cavity of the shape of a tube which is continuous above with the cavity of the brain case. Through this passes a thick cord-like prolongation of the brain known as the spinal cord. The human body is thus said to enclose two distinct tubes or cavities, one the *dorsal* (Lat. *dorsum*, back) surrounded by the skull and the arches of the vertebræ and containing the brain and the spinal cord, and the other the large *ventral* (Lat. *venter*, belly) cavity of the trunk, which contains all other internal organs.

The Digestive System.—This consists of a very long tube known as the *alimentary canal* (Lat. *alimentum*, nourishment), opening to the outside by the mouth above and by the *anus* at the lower end. Behind the throat the tube passes as the *gullet*, down the neck and the thorax, and on entering the abdomen becomes dilated into a pouch-like organ, the *stomach* in which the food remains for some time while a digestive fluid acts upon it. After leaving the stomach, the food passes through the whole length of the tube which is coiled on itself and known as the *intestine*, the first twenty feet or so being known as the *small intestine* and the remaining six feet, because of the wider diameter of the tube, as the *large intestine*.

The digestive fluids are poured into the alimentary canal from neighbouring glands and from the walls of the tube itself, while the food is passing through its various regions. The liver and the pancreas (or sweet-bread) are the two most important glands or secreting organs of the digestive system. The object of digestion is to change the food and convert it into a fluid state in which it should be capable of entering and becoming a part of the blood. After all the nourishment has been taken out of the food, the fæces, or what is left over, is passed out of the body through the anus. The anus is kept closed by a muscular ring, which only opens at the time of defection, and is known as the *anal sphincter*.

The Absorptive System consists of minute tubes or *lymphatic vessels* which collect the nutritious material from

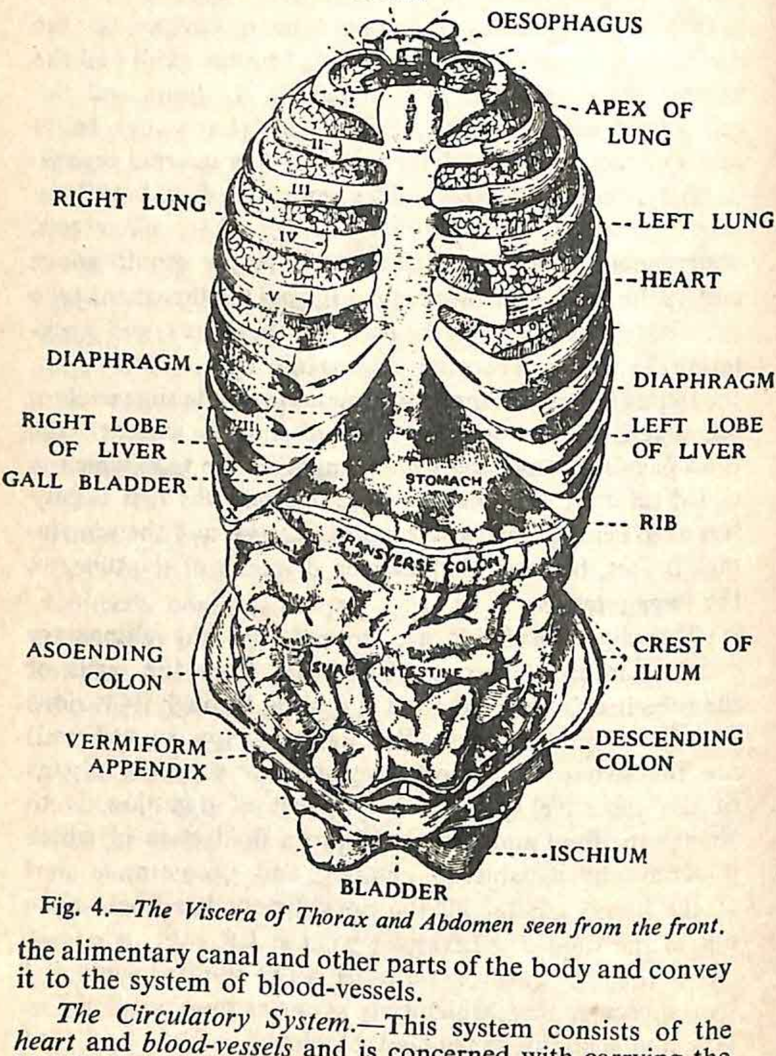


Fig. 4.—*The Viscera of Thorax and Abdomen seen from the front.*

the alimentary canal and other parts of the body and convey it to the system of blood-vessels.

The Circulatory System.—This system consists of the *heart* and *blood-vessels* and is concerned with carrying the blood to all parts of the body and bringing it back. The blood is the medium which keeps circulating or moving round within a system of closed tubes. It is from the blood that the nourishing substances pass out to the various

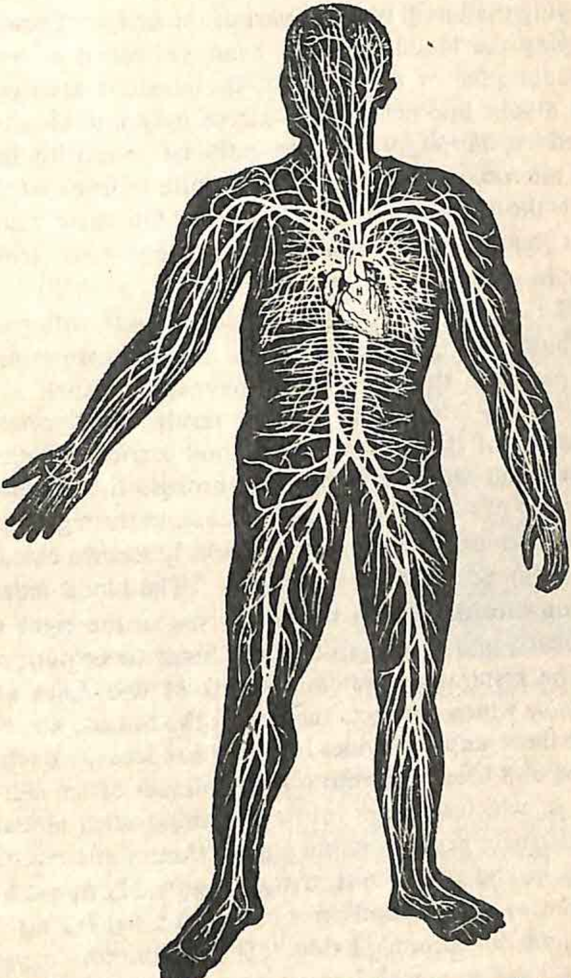


Fig. 5.—*The Circulatory System showing the Heart and the larger Blood-vessels.*

H, the heart. The arrows indicate the direction of the blood stream.

tissues and the waste products of their activity are thrown into the blood. The *heart* is a hollow muscular organ which, by its contractions, pumps the blood into vessels which repeatedly divide into smaller and smaller vessels, carrying the blood to every part of the body. These vessels carrying the blood from the heart are called *arteries*. In the substance of every organ, the smallest arteries break into a very fine network of exceedingly fine blood-vessels called *capillaries*, which can only be seen with the help of a microscope. The capillaries unite to form *veins* which carry the blood back to the heart. On their course the veins join one another, until finally a few large veins pour their blood into the heart.

The Respiratory System concerns itself with purifying the blood so far as its gaseous contents are concerned. All parts of the body need oxygen for their activity. The energy for work is the result of a process of oxidation of the tissues. The blood carries oxygen to the tissues, and while it is passing through the capillaries in any part of the body, oxygen passes out through their thin walls and carbon dioxide (popularly known as carbonic acid gas) passes into the blood. The blood laden with carbon dioxide returns through veins to the right side of the heart, and is sent out to the lungs to be purified.

The respiratory system consists of two *lungs* and the *windpipe* which connects them with the outside air. In the chest the windpipe divides into two branches. Each enters a lung and breaks up into a large number of smaller tubes, each of which enlarges into a tiny thin-walled *air-sac*. By the alternate expansion and contraction of the chest, air is taken in and passed out of the lungs. The impure blood circulating in the capillaries of the lungs takes up oxygen and gives out carbon dioxide. The blood is thus oxygenated and the air, now with less oxygen and more carbon dioxide than before, is breathed out of the body. This constant change of air in the lungs is known as *respiration* or breathing.

The Excretory System.—Besides carbon dioxide, the tissues discharge into the blood other more complex nitrogen containing waste products also. When the blood, in the course of its circulation, goes to the *kidneys*, the latter remove these waste products from the blood, and wash them out into the bladder in the form of a watery fluid called the urine. The *skin*, the *liver* and the *lungs* also act as excretory organs to some extent.

The Nervous System.—The brain, spinal cord and nerves, distributed to all parts of the body constitute the nervous system (Fig. 7). By means of these organs impressions are received from the outside world, and the working of all parts of the body is controlled and regulated. The eyes, ears, nose, tongue and skin are all connected by means of nerves with the brain where all the information is brought from the outside. The nerves may be compared to telegraph wires which are carrying messages from the various parts of the body to the brain and orders issued by the latter to the various muscles and glands to do their work as desired.

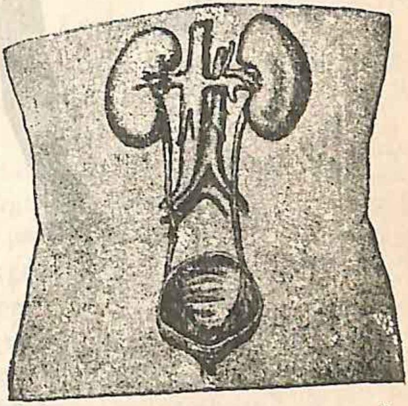


Fig. 6—*The Kidneys, Ureters and the Bladder.*

(From Cathcart's 'First Book of Physiology and Hygiene', Macmillan & Co. Ltd. By permission.)

The ureters are the tubes which bring urine from the kidneys to the bladder. The bladder is shown cut open to show the interior,

The Reproductive System.—Certain organs are set apart in the body for the reproduction of the species. Every plant and animal produces other beings similar to its own being. The organs differ in the male and the female, and by the union of a minute cell from the male called the *sperm*, with a cell from the female called the *ovum*, the *egg* cell is formed, which develops into a new individual. The

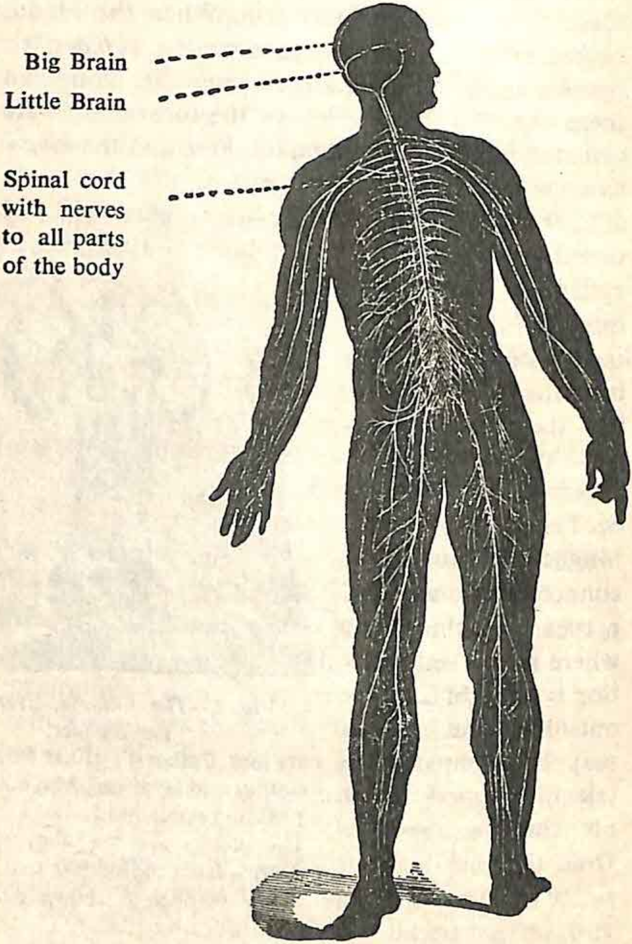


Fig. 7—General view of the Nervous System

testes in the male and *ovaries* in the female are the primary organs of sex, which produce the sperm and the ovum respectively while the sac-like structure in the mother's abdomen in which the child develops is called the *womb* or the *uterus*. Thus each little child that comes into the world begins as a seed in the body of its mother and gets its life from her. It is outside the scope of this book to treat of these organs but when you grow older and are about to marry you should read some good book on matters relating to sex and the responsibilities of becoming fathers and mothers.

Questions for Examinations

1. What do you understand by Physiology, and what do you gain by its study?
2. Give the properties of living matter.
3. What do you understand by the term "organ"? Name the chief organs of the body.
4. Describe the chief parts of the body.
5. Name the chief organs of —
   (*a*) Digestive system
   (*b*) Respiratory system
   (*c*) Circulatory system
   (*d*) Excretory system
   (*e*) Nervous system.
6. Name the organs of (a) Thorax (b) Abdomen.

CHAPTER II

THE COMPOSITION OF THE BODY

Tissues.—In the last chapter we have seen in a general way the organs which go to form the body. An examination of any organ shows that it is formed of one or more different kinds of materials or fabrics called tissues. Thus the brain and the nerves are formed of a soft greyish-white material called the *nervous tissue*. The red flesh is composed of *muscular tissues*, bones are formed of a hard compact substance, the *bony tissue*, and so on. When the skin is being removed, it will be found to be connected with the flesh underneath by means of a soft stringy substance known as *connective tissue*. This form of tissue is found to be very widely distributed in the body, covering every bone and every muscle, and binding together the different materials which go to form an organ. Bone and cartilage also are special varieties of connective tissue. Lastly, *epithelial tissue* is found covering the external surface of the body, and lining the entire length of the alimentary canal, and other tubular cavities and various glands and ducts in the body. In fact, wherever there is need for a smooth continuous membrane, epithelial tissue is found to occur.

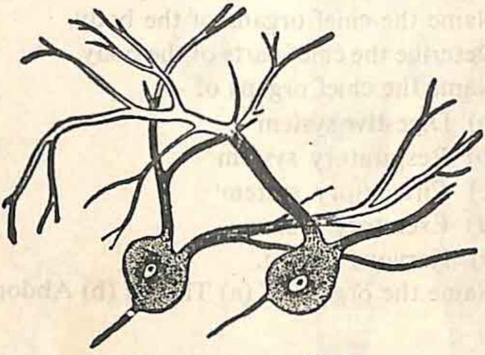


Fig. 8.—*Nerve Cells.*
(From Quain's 'Anatomy'. By permission.)
One process is covered with sheaths to form a nerve-fibre.

The Body as a Community of Cells.—When any tissue is examined with the aid of a *microscope*, it is found to be built up of a large number of similar units of living substance called *cells*, together with more or less binding material originally derived from them. Just as bricks are units of structure in building a house so also are cells the units of living substance which form a body. The body of every one of the higher animals and plants consists of myriads of such tiny units. Just as in an organized society or civilized community there is a division of labour, various groups of people following different occupations, such as agriculturists, blacksmiths, shoemakers, weavers, etc., so also in the body different kinds of groups of cells are set apart for the performance of different functions, and have come to vary in form according to the particular kind of work they perform. Every living being is developed from a single cell, the germ or egg cell, which is formed by the union of a male cell with a female cell. This cell goes on dividing repeatedly, and as the mass of cells grows, groups of cells become arranged together to form special tissues and organs. While doing so, they assume their characteristic shape and become fitted for their special work. Every tissue thus differs from another in the form and nature of its cells, and the way in which these cells are united together by intercellular substance. It would be interesting to consider what these different types of cells look like when seen under a microscope and the nature of the duties they perform. It must be remembered that a microscope provided with an ordinary high power lens magnifies an object four or five hundred times, that is to say, makes a pin's head appear to be the size of a cartwheel.

Each cell whether of nerve, muscle or connective tissue is made of a jelly like substance called *protoplasm*. The protoplasm inside the cell is called cytoplasm, and in it is a clear darker body, called the *Nucleus*. The protoplasm is the living material of which bodies of all animals and plants are composed. This is a very complex substance the composition of which keeps constantly changing and is different in different parts of the body. The outermost film of cytoplasm is called *cell membrane*. Chemicals which the cell needs can seep in and waste products can seep out of the cell membrane.

The *Nucleus* is usually an oval body lying near the centre of the cell. Inside, the nucleus are thread like fibres called *chromosomes* and the material filling the meshes of the network is a clear liquid called *nucleoplasm*. In the human cell chromosomes are 46 in number, but the number varies in different animals. The chromosomes carry even smaller particles called *genes*, which carry inherited characters from the parents and even from the grandparents.

The nucleus is chemically very active, and influences the growth, repair and division of the cell. The cystoplasm controls absorption and excretion, cell division provides for reproduction, growth and repair of the body. The characteristic activities of protoplasm are respiration, digestion, assimilation, excretion, reproduction and growth. Let us now study the structure and functions of various specialised cells.

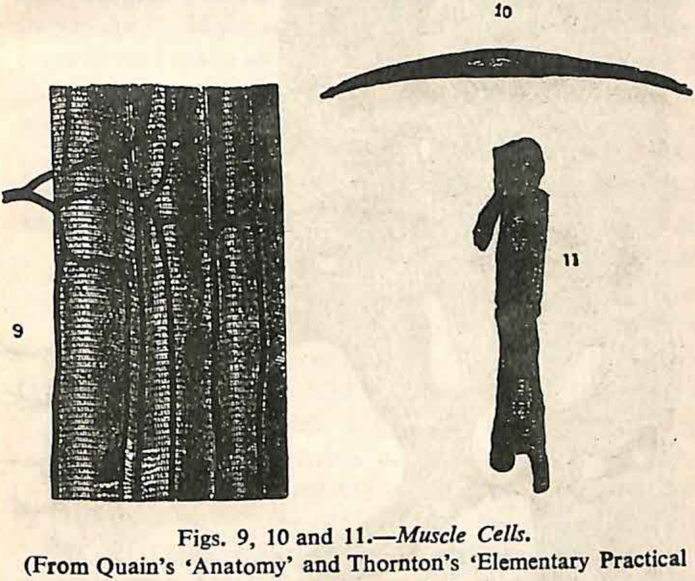
The Nerve Cells.—These cells are found in the brain and the spinal cord and are very varied in shape. Each cell has a nucleus, and several processes which branch and interlace with the branches of neighbouring cells. One of these processes is very much drawn out and covered with sheaths of other materials, thus forming a nerve-fibre. A nerve, as seen in a dissection, is a bundle composed of innumerable nerve fibres.

These cells with the fibres form the great telegraph system of the body. They are constantly carrying messages with great speed and the messages leap across from branches of one cell to those of a neighbouring one. Reports from all parts of the body are received by them. These cells are engaged in thinking and issuing commands and all the highest faculties of understanding and reasoning are due to their proper working.

The Muscle Cells.—These are the labourers in the body.

Each cell knows only how to do one thing, namely, to contract. It becomes shorter and thicker, with the result that a muscle composed of thousands of cells becomes shorter and thicker by all of them contracting altogether. Movements of different parts of the body are thus brought about.

The muscle cells forming the muscles of the limbs and other parts of the body which are under the control of the will, obey the commands received from the nerve cells. These muscle cells are so long and drawn out as to be usually referred to as *muscle fibres* and are marked across or *striped* (Fig.9). The unstriped muscle fibres are shorter and taper at both ends (Fig. 10). They are arranged so as to form thin sheets in the wall of the alimentary canal, and by



Figs. 9, 10 and 11.—*Muscle Cells.*
(From Quain's 'Anatomy' and Thornton's 'Elementary Practical Physiology'. By permission.)
Fig. 9, striped or voluntary muscle fibres; Fig. 10, unstriped or involuntary muscle fibre; Fig. 11, muscle fibres from the heart.

their contraction squeeze and push the food along and finally eject the fæces. They also occur in the wall of the urinary bladder. Lastly, the muscle cells composing the heart, though not working under the control of the will, are striped (Fig. 11) but they are very much shorter than ordinary striped muscle fibres.

The Connective Tissue Cells.—These cells are generally irregular in form and situated wide apart from one another, there being more intercellular substance in this kind of tissue than in any other.

As an example, a thin section of bone may be examined.

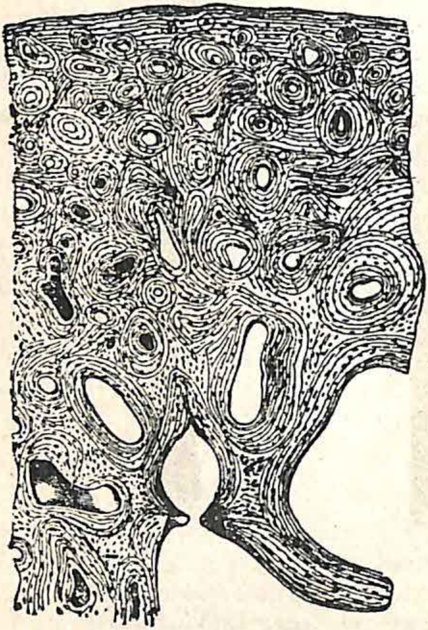


Fig. 12.—*Section of Bone.*

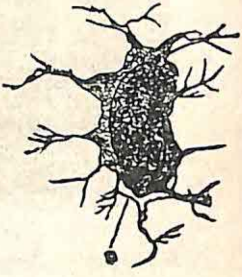


Fig. 13.—*A bone cell, very highly magnified.*

(From Quain's 'Anatomy'. By permission.)

The *bone cells* are tiny and of an irregular shape and are arranged in concentric rings round small canals which contain the blood-vessels. Bone also is a living tissue and the cells are nourished by the fluid oozing through the thin walls of the blood-vessels. It is characteristic however of these cells, that they surround themselves with walls of lime, and thus build up the supporting framework of the body.

Another important group of workers in the body are the *blood-cells* (Fig. 45). They do not combine to form a tissue, but float in a colourless liquid. The blood keeps flowing through tubes in the body, known as arteries, capillaries and veins. The blood-cells are of three kinds, red cells, white cells and platelets. The red cells are little rounded discs of a pale yellow colour, but on account of their vast numbers they make the blood appear of a beautiful red colour. They carry oxygen gas to all other cells in the body, without which the other cells could not live. The white cells are of an irregular shape and very much fewer in number. Each of these resembles a minute creature consisting of no more than a single cell called an amœba, which is found in pond water. Under the microscope the organism is seen to be constantly altering its form. As that organism engulfs its food, so these white cells in our body are seen to devour disease germs or other foreign particles which may gain their entry into the blood. The platelets are spherical or oval non-nucliated discs, and they play an important part in the arrest of bleeding and healing of wounds.

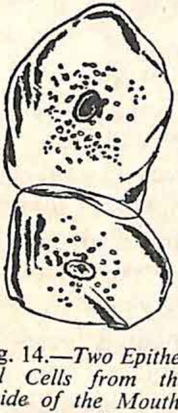


Fig. 14.—*Two Epithelial Cells from the inside of the Mouth.* (From Quain's 'Anatomy'. By permission.) Magnified 160 diameters.

Epithelial Cells.—These are found covering the surface of the body forming the skin, and lining the entire length of the alimentary canal, called the mucous membrane. The cast-off layers of the skin of a frog may be examined under the microscope to get a good idea of these cells, or numbers of them can be removed easily from your mouth-cavity by passing the tip of your finger across the inside of your cheek

Each cell is a tiny mass of living substance, and contains a denser central body as the *nucleus*.

In certain situations in the body another kind of epithelial cells manufacture lubricating or digestive fluids. Such cells are known as the *gland cell*s and in some places they combine together to form fairly big organs called the glands. Different glands manufacture different kinds of secretions which are in many cases carried away from the gland by special ducts or tubes to the required place.

Chemical Composition of the Body.—We have seen that the body is built up of organs, those of tissues, and tissues of cells. But from the point of view of the chemist, the whole body is composed of various chemical substances. The living material of which the bodies of all animals and plants are composed is known as *protoplasm*. This is a very complex substance, the composition of which keeps constantly changing, and is different in different parts of the body. Generally speaking, the following chemical elements are found in the body:—oxygen, nitrogen, hydrogen, carbon, calcium, phosphorus, sulphur, chlorine, fluorine, potassium, sodium, magnesium, and iron. The proportions in which these elements occur in the body are graphically represented in the accompanying diagram. Some of these elements are solids, while others are gaseous. Students should learn something about them from an elementary book on chemistry. In the body they are found to occur in the form of various compounds except the first three which occur in the gaseous state also.

Chemical Compounds of the Body.—In the body the elements are found combined together to form various compounds. This carbon dioxide is a gas formed by the union of oxygen with carbon, water is a compound of hydrogen and oxygen. Sodium chloride is a compound of the metal sodium with a gas called chlorine. Hydrochloric acid is a compound of hydrogen and chlorine

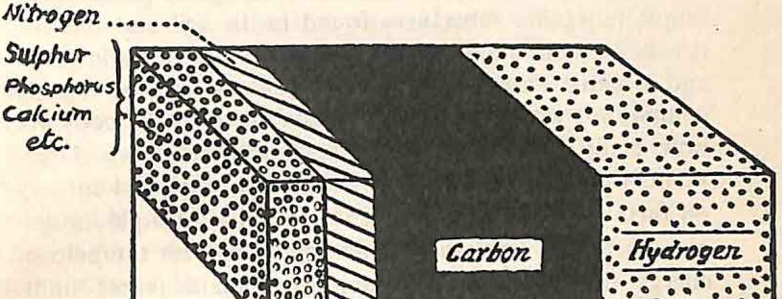


Fig. 15.—*Diagram to show the proportionate amount of Chemical elements in the body.*
(From 'Text Book of Biology' by W.M. Smollwood; Lea and Febiger, Philadelphia, U.S.A. By permission.)

and occurs in the digestive juice secreted by the stomach. Calcium carbonate is composed of calcium, carbon and oxygen and calcium phosphate is a compound of calcium, phosphorus and oxygen. These are both found in bones. All these compounds are known as *inorganic compounds*, as they are not confined to the bodies of plants and animals

15564

but are found in nature also. Besides these there are more complex compounds which always contain carbon as one essential part, and are confined to the bodies of the plants and animals. These are called *organic compounds*. They are originally built up or manufactured by the plants from simple inorganic substances found in the soil and the air. It may be mentioned that the distinction between inorganic and organic compounds is fast breaking up, as organic compounds which were only manufactured by the body are now being manufactured in the laboratories, e.g. Urea. Plants differ from animals in being able to depend entirely on their own resources, using for their food simple inorganic substances only and combining them with the help of energy derived from the sun, into organic compounds. Animals also take in water and some mineral-salts, but they could not live on these alone. They depend for their life on the organic compounds made by plants. Flesh-eating animals live on other animals, which in turn use plant food. It must be remembered that plants form these organic compounds for their own growth and store away some in their roots, stems or leaves for future needs, or in their seeds as a provision for the next generation.

There are three great classes of organic compounds, namely, *Proteins*, *Carbo-hydrates*, and *Fats*. They are found in different forms in the bodies of all plants and animals. Of these, *proteins* alone contain nitrogen in addition to carbon, hydrogen and oxygen, and consequently the body can be built from them alone. As examples of proteins may be mentioned glutenin found in wheat and other grains, legumin in peas, beans and lentils, albumen in the white of egg, casein in milk, and myosin in meat. *Carbo-hydrates* are composed of carbon, hydrogen and oxygen, with always twice as much hydrogen as oxygen and varying amounts of carbon. Common examples of carbo-hydrates are various kinds of starch and sugar. Starch is found abundantly in wheat or maize flour, rice grains and potatoes, and different kinds of sugar in sugarcane, beetroot and various fruits, etc. Carbo-hydrates are found almost entirely in plants, whose tissues are largely composed of these. When animals eat them, they are mostly oxidized to produce heat and energy. A small reserve of carbo-hydrate is always retained in our body as glycogen (a kind of starch found in the liver) and a sugar called glucose circulates in the blood and is found in other tissues, to be used by them as fuel. Any excess of carbo-hydrates over the requirements of the body is converted into fat and stored as a reserve of fuel. Lastly, *fats* are also composed of carbon, hydrogen and oxygen. They differ from carbo-hydrates in having less oxygen. Hence they oxidize more readily and so their chief use is to produce energy. Plants store fats or oils mostly in their seeds to supply energy for growth, and animals also store fats in various places in their body for various purposes. As examples of oils may be mentioned mustard oil, coconut oil, almond oil and of fats, butter contained in milk, and fat in between and surrounding the flesh of the animals.

It is obvious that substances of which our bodies are made, are the substances which are supplied in the food we take. We shall consider these classes of compounds again in greater detail in the chapter dealing with food.

What is going on in the Body? We eat food which always consists of five classes of compounds, viz. proteins, carbo-hydrates, fats, water and mineral salts. These are variously changed during the processes of digestion and ultimately enter the blood stream in a suitable form. They are then carried to all parts of the body and enter into composition of the cells and tissues of the body. The body thus grows. At the same time oxygen from the air is also taken in by the lungs and carried to all parts of the blood. By combining with various compounds composing the cells of the body, it serves to break them up into simple substances. One result of this process of oxidation or slow burning is that heat or energy necessary for all work is produced, but at the same time all parts of the body are being constantly broken down or undergoing waste. It must be clearly understood that all work whether physical or mental is at the expense of the breaking down of the body. Processes going on inside the body such as circulation of blood, respiration, etc., also require a certain amount of energy and involve a breaking down of the tissues. The simpler compounds that result from the process of breaking down, such as water, carbon dioxide, urea, etc., are to a great extent removed from the body, and it wastes and loses weight in showing life and activity. But the living body has the power of making good the loss by taking in food, and the tissues are able to repair or renew themselves. If the body is able to assimilate more than it loses, the net result is growth and increase in weight. The process of oxidation that goes on in the body may be compared to the burning or combustion of wood or charcoal that goes on after the fire is once kindled. The products of combustion if collected are found to be the same, viz. carbon dioxide and water and the incombustible portion of the food remains as mineral ash. Ordinary burning or combustion is rapid oxidation accompanied by light and heat, but the process in the body is a slow one and although heat is produced, there is no flame. The sum total of chemical changes in the tissues is called *metabolism*. The changes in which food materials are used in building the body are called *anabolic* or *anabolism* and the breaking down processes liberating heat and energy, and producing waste matters are called *katabolic* or *katabolism*.

When the metabolism is entirely limited to the vital functions of the body, such as working of the circulatory, digestive, respiratory, nervous and glandular activities, it is called *Basal Metabolism*. This is estimated when a person is at complete mental and physical rest for about 12 hours after taking food in a room at 20 °C. The heat generated under such conditions indicates the energy required to maintain vital processes, and is expressed in calories per square metre of body surface per hour. The average for healthy persons between the age of 20 and 50 years is between 36 and 40 calories. Clinically, Basal Metabolism is determined on the basis of oxygen used and carbon dioxide produced by the individuals and is determined by an apparatus called Spirometer.

Body and a Steam-engine compared.—The human body is often compared to a steam-engine. Both need a supply of food (fuel) and both require oxygen to unite with the food and set free its energy. In both, heat is the result of oxidation. In the engine this heat produces steam, the force of which is utilized to move the wheels. In the body the energy set free manifests itself in muscular movements and other kinds of work. In both, waste products result from the process and these have to be removed. In the body some parts of the food taken are left unused, in the engine fire ashes are left behind. The comparison ends here. An engine or any other machine cannot obtain its own food. It does not assimilate or grow. It cannot repair itself. It requires an outside being to start, direct and control it. It cannot reproduce its kind. A living organism only can feed, grow, and reproduce. The human body is a machine, but it is a wonderful machine that has the power of growth, self-repair and reproduction. It is further capable of starting and controlling its own working and can give a suitable response to the outside force working on it.

Questions for Examinations

1. Define "cell", "tissue". Describe the elementary tissues of the body.

2. Explain the statement "The animal kingdom illustrates the principle of division of labour".
3. Define "Muscle", "Nerve", "Connective" tissue.
4. Briefly describe the chemical composition of the body.
5. Compare the human body with a steam-engine.
6. What do you understand by "Metabolism", "Anabolism" and "Katabolism"?

CHAPTER III

THE SKELETON

THE SKULL

The Bony Skeleton.—In a previous chapter we have considered the general build of the body. We shall now devote our particular attention to the *Skeleton* and the various bones of which it is formed. The skeleton contains over two hundred separate bones united together to form various *joints*. The important functions of the skeleton are (1) to support the soft parts and thus give shape to the body. (2) to protect important organs, and (3) to serve for the attachment of muscles, (4) supply calcium to the blood and (5) form red blood cells in the bone marrow. The bones forming the skeleton are of various kinds. Some are *flat* bones, like those of the skull, others are *long* like those of the extremities. The bones forming the wrist and the ankle are *short* bones, while those forming the vertebral column are known as *irregular* bones.

All the bones are covered with a membrane, called the Periosteum, which contains blood vessels to nourish the bones. The inside of the shaft of long bones is hollow, and is called the medullary cavity. It contains yellow marrow which is fatty in character, while the interior of ends of long bones and of flat, short and irregular bones is spongy, and contains red marrow. Red blood cells and some white blood cells are formed in the red marrow.

The skeleton may conveniently be divided into four parts:—

1. The Skull or the bones of the head and the face.
2. The Vertebral Column or the back-bone.
3. The bones surrounding the cavity of the thorax.
4. The bones of the upper and the lower extremities or limbs

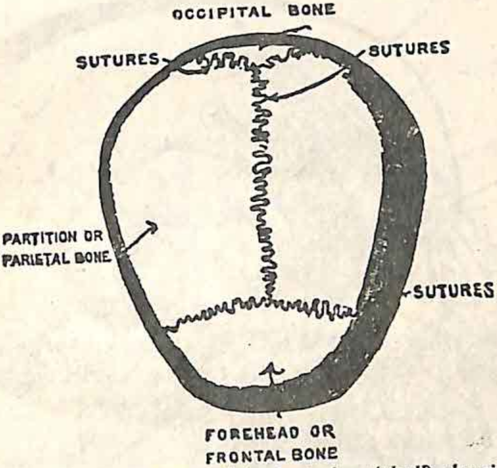


Fig. 16.—*A view of the top of the brain-box (skull) showing the position of the bones and their sutures.*

The Skull.—The skull consists of the bones of the head and may be divided into the Cranium or the brain-box and the bones of the face.

The Cranium is the large bony box which contains the brain and is composed of eight flat bones, firmly united together by the saw-like edge of one bone interlocking with the edge of another bone to form a bony union known as a *suture*. These bones are:—

One *Frontal* bone.
Two *Parietal* bones.
Two *Temporal* bones.
One *Occipital* bone.
One *Sphenoid* bone.
One *Ethmoid* bone.

The *Frontal bone* forms the forehead or the front of the cranium. It also forms the root of the orbits or sockets for the eyes, and the upper portion of the nose.

The two *Parietal bones* form part of the side and the roof, and are united to the frontal bone in front, the temporals below and to the occipital behind.

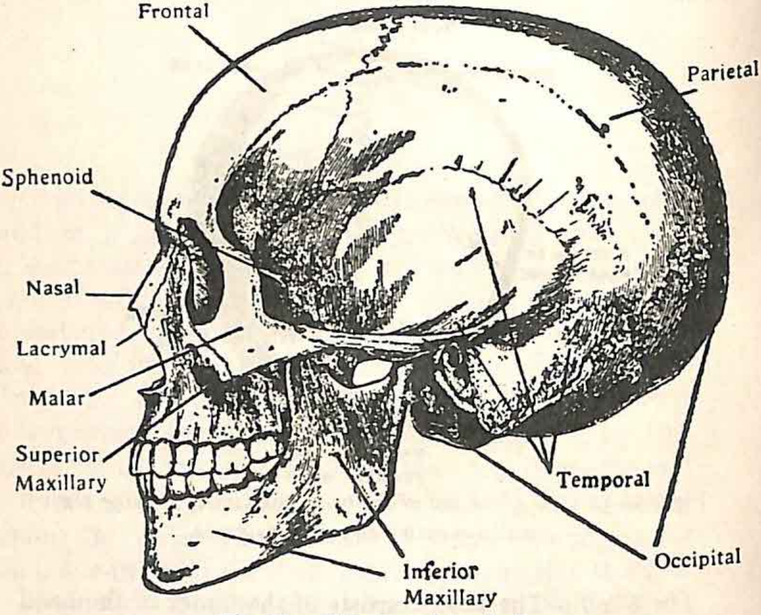


Fig. 17.—*Side view of the skull.*
(From Quain's 'Anatomy'. By permission.)

The two *Temporal bones* form the temples and complete the side-walls of the skull. The bone on each side contains a narrow canal leading to the middle ear. Behind the opening is a marked projection, in front of which is a smooth depression into which the upper end of the lower jaw fits. The internal ear or the essential organ of hearing is contained inside the pyramid-shaped projection on the inside of the bone.

The *Occipital bone* forms the back of the head and is united above to the two parietal bones. In its lower part the occipital contains a large hole, the *foramen magnum*, through which the brain becomes continuous with the spinal cord. On each side of the foramen magnum are two smooth projections, the *condyles*, which move on the first vertebra, thus permitting the nodding movements of the head.

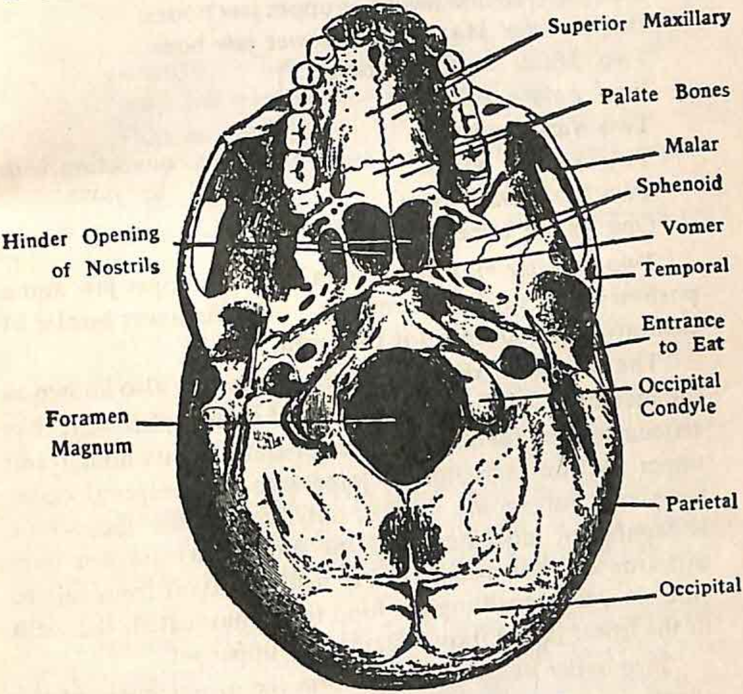


Fig. 18.—*The under surface of the skull.*

The *Sphenoid* is a bat-shaped bone and forms a portion of the base and the sides of the skull. It unites with the occipital bone behind the temporals on the sides and several other bones of the skull.

The *Ethmoid* is a small bone lying in front of the sphenoid forming the roof of the nose and part of the side-walls of the orbit. It is perforated like a sieve to allow the passage of small twigs of the nerves going to the nose.

The *face* is formed of fourteen bones all of which except the lower jaw, are immovably united with the cranium. These are :—

Two *Superior Maxillary* or upper jaw bones.
One *Inferior Maxillary* or lower jaw bone.
Two *Malar* or Cheek-bones.
Two *Palate* bones.
Two *Nasal* bones.
Two *Spongy* bones.
Two *Lachrymal* bones.
One *Vomer* bone.

In connection with the nose.

Two *superior maxillary* bones form the upper jaw and a portion of the roof of the mouth. On the lower border of each are eight sockets for the teeth.

The *inferior maxillary* or lower jaw bone is also known as the mandible. It forms the chin and on its upper edge has sixteen sockets for the lower set of teeth. By its hinder and upper part on each side, it joins with the temporal bone, forming a hinge joint. It is the only bone of the face which is capable of movement and the movements are not only upwards and downwards but to a slight extent from side to side also, thus enabling the food to be masticated, the teeth in the lower jaw working against the upper set.

Two *malar* or cheek-bones form the prominences of the cheek.

Two *palate* bones form the upper part of the palate.

Two small *nasal* bones form the upper part of the bridge of the nose, the rest of the nose being formed of cartilages.

Two *spongy* or twisted bones one in each chamber of the nose. They are small scroll-like bones which are twisted about so as to increase the extent of the membrane lining the nose.

Two small *lachrymal* bones, one situated in the inner well of each orbit, contain the passage for carrying off the tears from the eyes to the nose.

One *vomer* bone forms the back part of the middle partition in the nose.

Questions for Examinations

1. Describe the functions of the bony skeleton.
2. Name the bones of the skull, the face.
3. What are sutures?
4. What is the difference between head skull, and cranium?
5. What are the differences between the upper and the lower jaw?

CHAPTER IV

THE SKELETON (*continued*)

BONES OF THE TRUNK

The Vertebral Column.—The 'back-bone' of the vertebral column consists of thirty-three irregular bones superimposed one upon the other and united by strong bands of fibrous tissue.

The upper twenty-four bones, forming the neck, back and loins, are separate and slightly movable, and the lower nine are fused together. The individual bones are known as vertebræ and between one vertebra and another is a pad of cartilage. The cartilages act as buffers and serve to distribute any shocks or jars, produced in jumping, etc.

The various vertebræ are named according to the position in which they are found. The *cervical vertebræ* found in the neck are seven in number. The next twelve are called the *dorsal* or thoracic vertebræ forming the upper part of the back. These give attachment to the twelve pairs of ribs. The remaining five movable vertebræ are known as the *lumbar* vertebræ and form the lower part of the back. The lowest of these rests upon a large wedge-shaped bone called the *sacrum*, formed by the fusion of five sacral vertabræ. To the lower end of this is attached the *coccyx* or the tail bone formed of four small vertebræ fused together.

On either side, the sacrum is united to two large hip bones which meet in front, forming a basin-shaped cavity called the *pelvis*.

All vertebræ except the first two are constructed on the same plan. To study this plan a typical vertebra may be taken, say from the middle of the thoracic region. It consists of the following parts (Fig. 20):—

(1) The *body*, the solid disc forming the anterior part of the bone, to the back of which is attached (2) the *neural arch* which encloses the spinal canal; and arising from the arch are (3) three processes of projections, two *transverse*, one on each side, and one *spinous* pointing backwards and downwards. The spinous

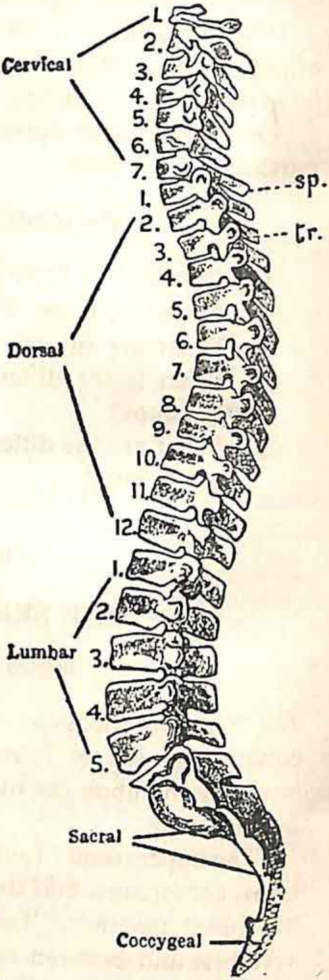


Fig. 19.—*The Vertebral Column viewed from the left side.*

process can be readily felt in the back. These processes give attachments to the various ligaments which hold the bones together and to the various muscles which enable us to bend the back.

The vertebræ in the various regions have the same parts as the typical dorsal vertebræ described above, but show marked distinctions peculiar to each region. The weight and size of the vertebræ increase from above downwards, so that the lumbar vertebræ are the heaviest and the largest while the cervical are light and small. The transverse processes of the cervical vertebræ are perforated, a blood vessel passing through the holes on either side. The dorsal vertebræ have long spinous processes and smooth areas on either side of the body and near the tips of their transverse processes, for the ribs to join.

The lumbar vertebræ have thick and strong transverse and spinous processes.

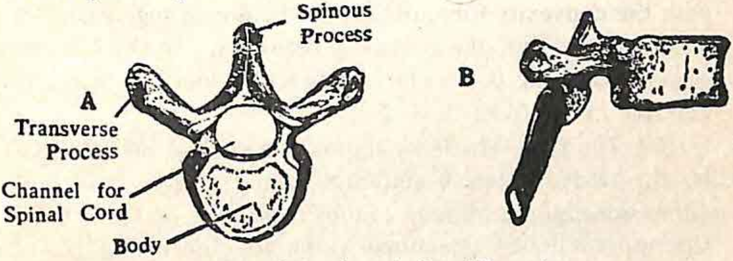


Fig. 20.—*A Dorsal Vertebra. A. viewed from above; B, viewed from the right side.*

(From Quain's 'Anatomy': By permission.)

Note the smooth surfaces near the tip of the lateral processes and on the sides of the body, for articulation with the ribs. These smooth surfaces are only found on the dorsal vertebræ.

We now turn our attention to the first two vertebræ which show marked peculiarities. The first cervical vertebra is called the *atlas*, as it supports the globe-like head. It is ring like, and has practically no body, but has two smooth articular surfaces on its upper side over which the condyles of the skull can easily move forwards and backwards. The spinous process is very rudimentary.

The second cervical vertebra is called the *axis*. It has on the upper surface of its body a peg-like process called the *odontoid process*, which fits into the ring of the atlas. It is kept in position by a transverse ligament which passes across the atlas. It will thus be seen that in turning our head from side to side, the atlas bearing the skull rotates round the odontoid process of the axis.

When the vertebræ are arranged in a column, with the intervertebral discs between them, and the processes of the vertebræ bound together by ligaments, they form a strong flexible support. The neural arches of the vertebræ then form a long bony tube, known as the spinal canal which contains and protects the spinal cord.

The column does not form a straight pillar, but has several curves. The cervical region shows a small curve with the convexity forwards, while the dorsal region shows a large curve with the concavity forwards. In the lumbar region again the convexity is forwards while the sacral is concave in the front.

The Thorax.—The bony thorax is a conical cage formed by the twelve thoracic vertebræ behind, twelve ribs on either side and the sternum of the breast bone in front. Only the upper ten ribs are united to the sternum by means of cartilages, the last two are not connected with the sternum and are hence called floating ribs. The function of the bony cage is to contain and protect the heart and the lungs and also to protect the liver, spleen and kidneys which though lying in the abdomen are covered by the ribs.

The *sternum* or the breast bone is a flat bone 6 to 7 inches long, broad at its upper end and narrowing towards the lower. It consists of three parts, the lowest of which is formed of cartilage. To the upper part the collar bones join on either side. On both sides of the sternum, the upper seven costal cartilages join the ribs with the sternum, the remaining three cartilages unite each other and with the seventh costal cartilage.

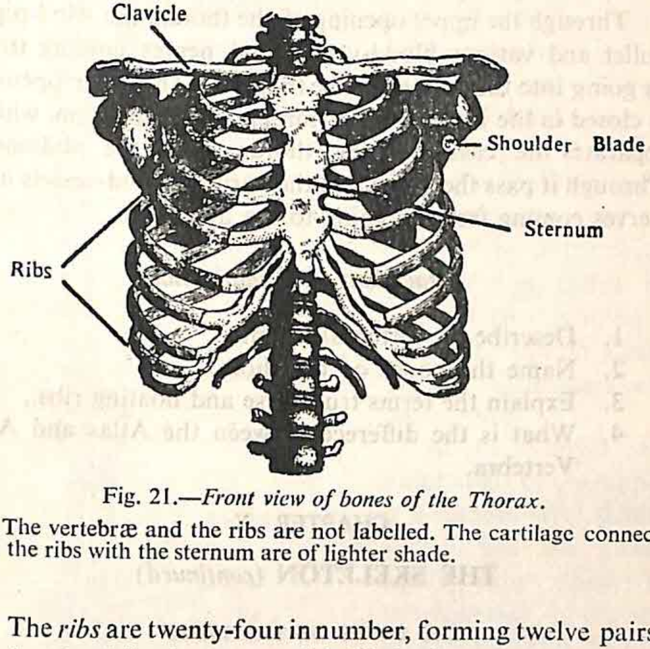


Fig. 21.—*Front view of bones of the Thorax.*

The vertebræ and the ribs are not labelled. The cartilage connecting the ribs with the sternum are of lighter shade.

The *ribs* are twenty-four in number, forming twelve pairs. Each pair of ribs is connected behind with a dorsal vertebra and except the last two pairs, with the sternum in front. The upper seven ribs are connected with the sternum by separate pieces of cartilage called the costal cartilages, and are called *true* ribs, the costal cartilages of the next three pairs are connected with each other and then with the costal cartilages of the seventh rib, and are called *false* ribs. The eleventh and twelfth ribs are the shortest; they do not reach the sternum at all, and are hence called *floating* ribs. The ribs are curved bones and are not placed horizontally but incline downwards and forwards.

The spaces between the ribs are called intercostal spaces and in life are occupied by intercostal muscles. These muscles are flat pieces attached to the edges of the ribs above and below, and by raising the ribs enlarge the chest cavity during respiration.

Through the upper opening of the thorax, the wind-pipe, gullet and various blood-vessels and nerves coming from or going into the neck enter the thorax. The lower opening is closed in life by an arching muscle, the diaphragm, which separates the cavity of the thorax from the abdomen. Through it pass the gullet and the various blood-vessels and nerves coming from or going to the abdomen.

Questions for Examinations

1. Describe the vertebral column.
2. Name the bones of the thorax.
3. Explain the terms true, false and floating ribs.,
4. What is the differece between the Atlas and Axis Vertebra.

CHAPTER V

THE SKELETON (*continued*)

THE BONES OF THE LIMBS

The Upper Extremity.—Each upper extremity is made up of the *shoulder*, the *upper arm*, the *forearm*, the *wrist* and the *hand*. The bones of these parts are as follows:—

The clavicle or collar bone, and the *scapula* or the shoulder blade, together forming the *shoulder girdle*, which serves to connect the arm with the trunk.

The *humerus* or bone of the upper arm.

The *radius* and the *ulna* in the forearm.

Eight *carpals* or wrist bones.

Five *metacarpals* or bones in the palm of the hand.

Phalanges or finger bones, three in each finger and two in the thumb.

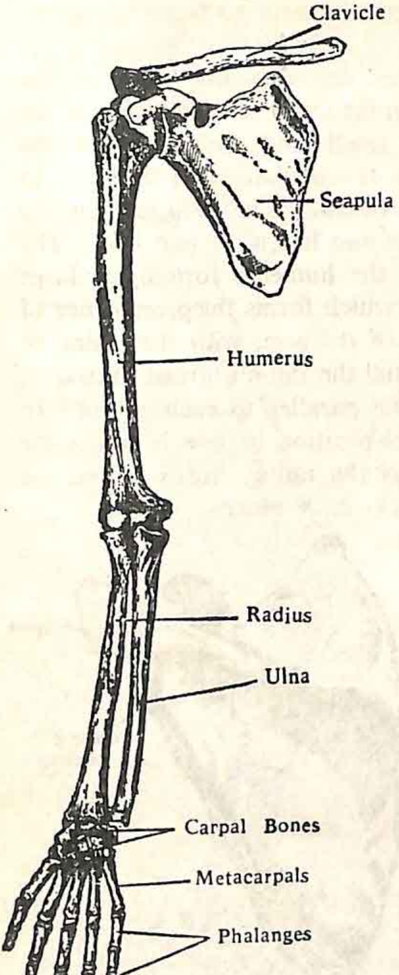


Fig. 22.— *Bones of the Upper Limb.*

The *clavicle* is a long curved bone joined with the sternum on the inner side, and with the scapula on the outer.

The *scapula* is a flat triangular bone lying on the back over the upper ribs. Its back surface is divided into two unequal portions by a transverse ridge of bone called the *spine* which expanding at its outer end into a large process articulates with the clavicle.

At the upper and outer angle of the scapula is a smooth oval depression, called the *glenoid cavity,* into which fits the rounded upper end of the humerus, to form the shoulder joint. The scapula is attached to the chest only by means of muscles and ligaments and has thus a free range of movement.

The humerus or upper arm bone is a long bone consisting of the head at the upper end, the shaft, and the lower end. It articulates above with the glenoid cavity of the scapula to form the shoulder joint, and below with the bones of the forearm to form the elbow joint.

The *radius* and the *ulna* are the two bones in the forearm. The *radius* lies on the inner or thumb side of the forearm. Its upper end is small and rounded and the lower broad and expanded. It articulates with the humerus above and the wrist bones below. The *ulna* lies on the same side as the little finger and has a larger end. The upper end articulates with the humerus forming a large joint and has a projection which forms the prominence of the elbow. In the position of the arm, with the palm of the hand facing forwards and the thumb turned outwards, the radius and the ulna lie parallel to each other. In turning the hand from this position to one is which the thumb is turned inwards, the radius turns round the ulna and the two bones cross each other.

The *carpus* or wrist is made of eight small *carpal* bones arranged in two rows. Being made of small bones, held in position by ligaments, the wrist is flexible and has a great range of movement.

The *metacarpal* bones are five in number and lie beyond the carpal bones, forming the palm. They articulate with the carpal bones above and with the phalanges below.

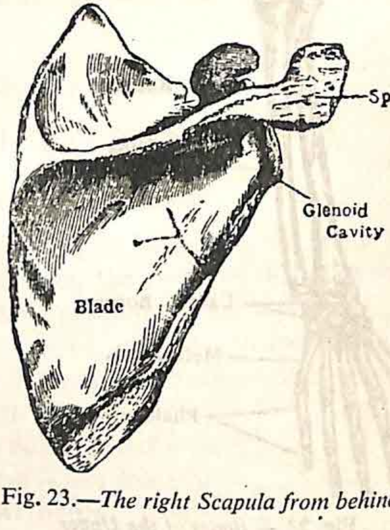


Fig. 23.—*The right Scapula from behind.*

The *phalanges* are fourteen in number, three in each finger and two in the thumb.

The Lower Extremity:—The lower extremity is made

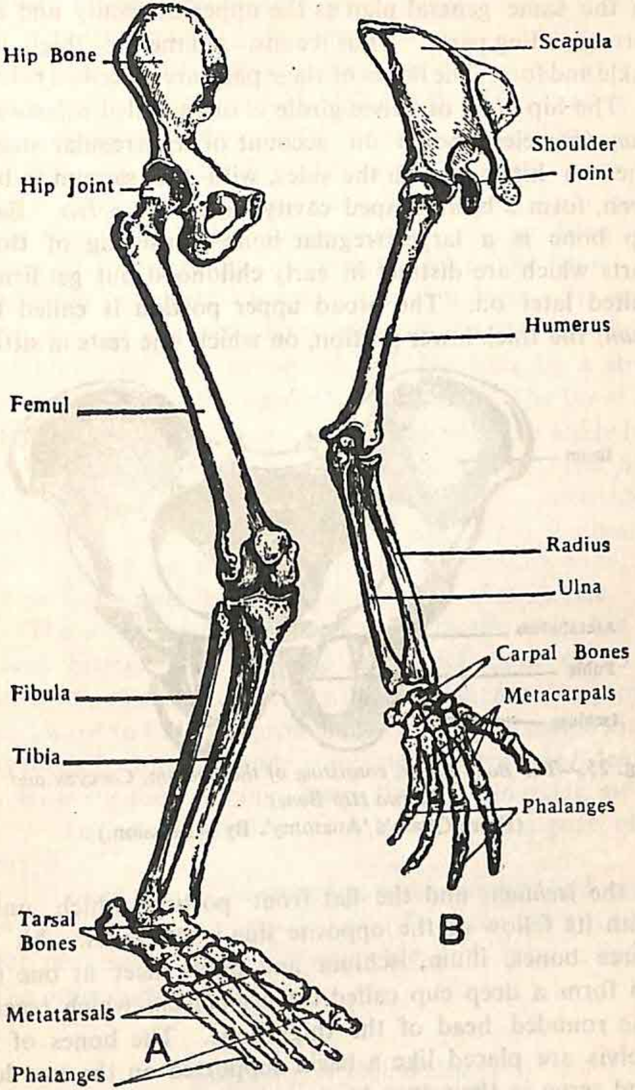


Fig. 24.—*The Bones of the Upper and Lower Extremities so placed as to show corresponding parts.*

on the same general plan as the upper extremity and has corresponding parts. Thus it consists of the hip, thigh, leg, ankle and foot. The bones of these parts are described below.

The hip bone or pelvic girdle is often called *osinnominatum* (nameless bone) on account of its irregular shape. The two hip bones on the sides, with the sacrum in between, form a basin-shaped cavity called the *pelvis*. Each hip bone is a large irregular bone consisting of three parts which are distinct in early childhood but get firmly united later on. The broad upper portion is called the *ilium;* the thick lower portion, on which one rests in sitting is the *ischium*; and the flat front portion which unites with its fellow of the opposite side is the *pubis*. All the three bones, ilium, ischium and pubis meet at one end to form a deep cup called the *acetabulum* which receives the rounded head of the thigh bone. The bones of the pelvis are placed like a basin supported on the two legs, and serve in their turn to support the organs lying in the abdomen.

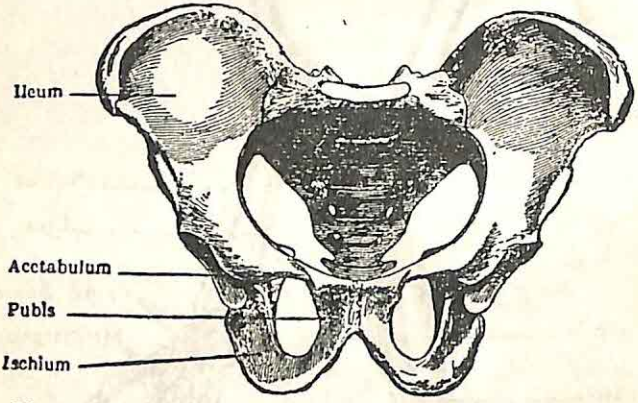


Fig. 25.—*The Bony Pelvis, consisting of the Sacrum, Coccyzx and the two Hip Bones*
(From Quain's 'Anatomy'. By permission.)

The *femur* or thigh bone is the longest bone in the body and corresponds to the humerus in the arm. At its upper end it has a circular knob-like *head* which fits into the acetabulum to form the hip joint. The lower end is expanded and articulates with the tibia of the leg.

The *tibia* and the *fibula* are the two bones of the leg, corresponding to the radius and the ulna of the forearm. The *tibia* is the larger and the inner of the two bones and has a sharp projecting edge which is felt as the 'shin.' It is therefore popularly known as the shin bone. Its upper end is large and articulates with the femur. In front of the knee joint and connected with the tibia by a strong thick ligament is the *patella* or knee cap. The lower end of the tibia is smaller and articulates with the ankle bone to form the inner prominence of the ankle. The *fibula* is a long thin splint-like bone placed on the outer side of the tibia. Unlike the radius and the ulna, it does not rotate round the tibia but is fixed to it at both ends. Its lower end forms the outer prominence of the ankle.

The ankle or *tarsus* corresponds to the wrist but has seven bones. One of these is a thick bone called the *astragalus* which articulates with the tibia; another projects backward to form the prominence of the heel and is known as *oscalcis*. Into this bone is inserted the *tendon of Achilles*, a large tendon coming from the calf muscles of the leg. The remaining five tarsal bones form a part of the instep.

The *metatarsal* bones are five in number and correspond to the metacarpal bones. To these are articulated the *phalanges*, two in the great toe, and three in each of the other toes.

Questions for Examinations

1. Name the bones of upper and lower limbs.

2. In what respects does a child's skeleton differ from that of an adult ?
3. Compare the bones in the upper and lower extremities.
4. Describe the pelvis.

CHAPTER VI

JOINTS, MUSCLES AND MOVEMENTS

Joints—Where two bones meet, they form a joint. Joints are either movable or fixed. In fixed joints such as between the bones of the cranium, bones meet each other, but are incapable of any movement. In these the bones are interlocked by small processes from each fitting into indentations of the other, thus forming what are called *sutures* (see Fig. 16).

In the *movable joints* bones are capable of movement, the extent of which varies in different cases. These are classified under four heads:—

1. *Ball and Socket joints.*—In these joints, the globular head of a long bone fits into a cup-shaped hollow of another bone. As examples may be mentioned the hip and the shoulder joints. These joints are characterized by great freedom of movement.

2. *Hinge joints.*—In these, movement occurs backwards and forwards in one plane just like a door or the lid of a box moving on a hinge. Examples of the kind are at the elbow, the knee, the ankle and the joints between the phalanges of the fingers and toes.

3. *Pivot joints.*—In these joints, one bone forms a pivot or a peg, round which the other rotates; for example the joint between the atlas and the axis vertebræ which enables the head to move from side to side.

4. *Gliding joints.*—In these joints, there is a slight gliding movement of one bone over another, usually through the interposition of a pad of cartilage. Examples of such joints are the articulations of the bones of the wrist and the joints between the various vertebræ.

Ligaments.—The bones are bound together by tough, white fibrous bands called *ligaments*. They are more or less elastic and thus allow some freedom of movement to the bones. The ligaments can be observed after removing the muscles covering a joint. The muscles will be found united to bones by other white *bands* called tendons.

Cartilage is a hard, but flexible substance. The external ear is a cartilage covered by thin muscles and skin. There is also cartilage forming the greater portion of the nose. There are flexible pads of cartilage between the bodies of the vertebræ enabling us to bend the back. These pads of cartilage also serve to deaden the effect of a shock which would otherwise be felt in jumping. There are also cartilages which connect the ribs with the sternum and thus serve to form a flexible framework.

Cartilage is also found to cover the ends of long bones where they meet each other in forming a joint. Cartilaginous surfaces are smooth and the ends of bones glide over each other more easily. In the case of ball and socket joints the lining cartilage serves to deepen the cup which is better able to hold the rounded end of the bone which fits into it.

Formation of a Movable Joint.—In order that movement in a joint may take place smoothly and without, friction, the ends of the bones forming a joint are covered with a layer of smooth cartilage. To further reduce friction to a minimum, the joints are lined by a delicate membrane which secretes an oily substance *synovia* which serves to lubricate it. To keep the bones in position the joint is covered by a loose bag of fibrous tissue called the capsule of the joint, which is strengthened on the outside by muscles.

As an example of a typical movable joint the parts entering into the formation of the hip joint may be studied.

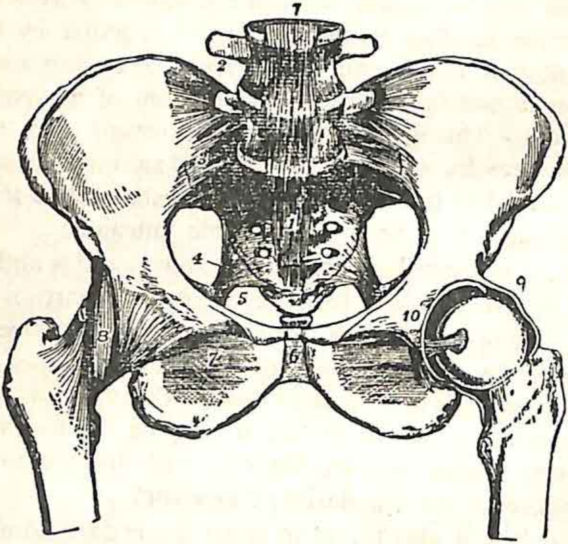


Fig. 26.—*Articulations of Pelvis and the ball and socket of the hip.* (From Quain's 'Anatomy'. By permission.)

1, ligament passing from vertebræ to sacrum; 2, 3, 4, 5, 6 and 7, other ligaments; 8, capsular ligament of hip joint on the right side, on left side the capsular ligament has been removed and femur turned outward to show the synovial cavity and round ligament; 9, and 10, cut edge of capsular ligament.

Here the ball-like head of the femur fits into the cup-shaped acetabulum of the hip bone. The head of the femur is covered by cartilage and the cup is lined by a rim of cartilage. A round ligament passes from the head of the femur to the bottom of the cup inside the joint. The capsular ligament surrounds the joint. This is lined by a synovial membrane which secretes the lubricating fluid.

The capsule is surrounded by muscles. The thigh can be bent or flexed at the hip by the muscles passing in front and straightened again by large muscles attached behind to the hip bone.

Muscles.—We have learnt in the first chapter that the flesh covering the different parts of the body is composed of a large number of distinct bands or *muscles* and that the various movements are produced by the contraction of these muscles. The muscles of the limbs, trunk and face are under the control of the will and are described as *voluntary* while those composing the wall of the stomach, intestines and the heart are not so controlled and are known as *involuntary*. The heart or cardiac muscles, however, have the power of originating rhythmic contractions and conducting waves of contractions from fibre to fibre, thus causing heart beats.

The voluntary muscles are of various shapes. Those of the limbs are usually thicker in the middle than at the ends where they are often continued into *tendons*, which serve to connect them to the bones. Some muscles may be directly fixed to the membrane covering a bone. A muscle may have more than one tendon at one of its ends. One end of a muscle is fixed to one bone, and the other end to another, the muscle thus passing over a joint. When the muscle contracts one bone is brought nearer to the other. Thus the biceps muscle raises the forearm, bringing it closer to the upper arm. As it contracts the muscle becomes shorter and thicker. The relatively fixed point is known as the *origin* of the muscle, while the point of attachment to the more movable part is known as the *insertion* of the muscle. Thus the biceps muscle has its origin on the scapula by two heads or tendons (Lat. *bi*. two; *caput*, head) and is inserted on the radius.

In other cases the muscles are in the form of thin broad sheets, such as the muscles forming the front and side walls of the abdomen and the diaphragm. The abdominal muscles by their contraction compress the abdominal cavity and the arching diaphragm becomes flatter during its contraction and thus increases the cavity of the thorax during inspiration.

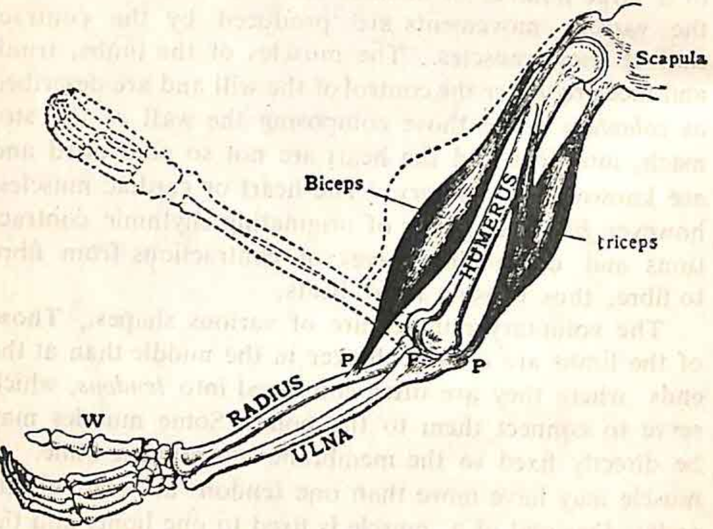


Fig. 27.—*The action of the biceps and triceps muscles.*
The biceps bends the arm at the elbow joint, and the triceps straightens or extends it; P and P', insertion of muscles where the power acts; F, fulcrum; W, weight or resistance.

The Bony Levers.—The muscles in producing motions of different kinds use the bones as levers. The term *lever* is taken from the science of mechanics and means a rigid bar or rod which moves about a certain fixed point called the *fulcrum*. You may have seen a man trying to raise a heavy stone with a crowbar. He places one end of the bar under the stone and presses down the other end. Here the bar is the lever and the ground under the bar serves as the fulcrum. The force which the man applies is called the *power* and the stone is the *weight*. Levers are divided into three orders, according as the fulcrum, the weight or the power is in the middle.

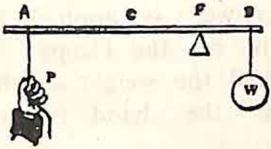


Fig. 28.—*Lever of first order*, (from Tate's 'Mechanism'. By Permission.)
Fulcrum in the middle.

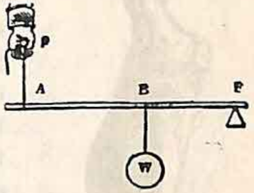


Fig. 29.—*Lever of second order*. (From Tate's 'Mechanism'. By permission.)
Weight in the middle.

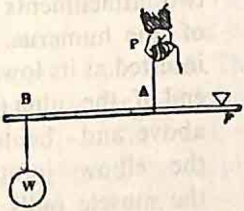


Fig. 30.—*Lever of third order*.
(From Tate's 'Mechanism'. By permission.)
Power in the middle.

In the case of movements in the body, the fulcrum is the joint about which the movement takes place; the power is applied at the point of insertion of the muscle which causes the movement, and the weight is the resistance, offered by the bone that is raised.

Two kinds of levers are illustrated in the bending or flexion and straightening or extension of the forearm illustrated in fig. 27. In both these cases the fulcrum is at the elbow. The bending is brought about by the biceps acting at its insertion on the radius. Here the radius serves as a lever of the third order, as the fulcrum is at the elbow joint, the power is applied at the insertion of the biceps on the radius and the weight of the forearm and the hand further down.

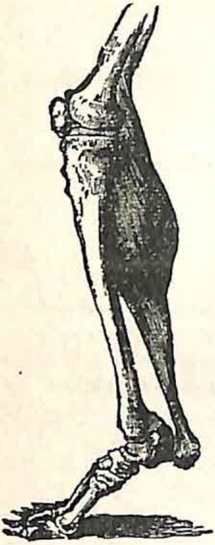


Fig. 31.—*Gastroenemius* Muscle. (From, Wilson's 'Physiology'. W. and R. Chambers, Ltd. By permission.)

The opposite movement of straightening or extension of the forearm is brought about by the triceps muscle situated behind the humerus. Its origin is by a tendon attached to the scapula and two attachments at the upper end of the humerus. The muscle is inserted at its lower end to the upper end of the ulna (Fig 27 P') a little above and behind the fulcrum at the elbow joint. In contracting, the muscle pulls the upper end of the ulna upwards and thus straightens the fixed arm. In this case, therefore, the ulna acts as a lever of the first order.

When we stand on tiptoe (Fig. 31) the fulcrum is the ground on which the toes rest, the power required to raise the body off the ground is applied by the muscles of the calf at the point where the tendon of Achilles is inserted on the heel bone, and the weight of the body falls on the bones of the foot. The weight being in the middle, this is an example of a lever of the second order.

Standing, Walking and Running.—We have considered above a few examples of movements of the limbs; it remains now to consider how the body as a whole maintains its erect position and performs such movements as walking, running, jumping, etc. The erect position of the body is secured by a complex arrangement of muscles, in front and behind the body, which balance each other; those in front pulling forwards and those behind backwards. The weight of the body falls on the tarsal bones of the foot, and there is a tendency for the leg to fall forward. This is counteracted by the great muscles of the calf. The ankle-joint is thus kept stiff; similarly, the knee-joint is kept from yielding by muscles passing before and behind it. The muscles in front of the thigh pull the body forward, but the muscles of the buttocks tend to pull backward. The trunk is thus supported at the hip joints by the muscles passing from the trunk to the thigh before and behind. The action of the muscles along the vertebral column would pull the body backwards and this is balanced by those in front of the abdomen and throat. Finally, the head is prevented from falling forward by the action of the muscles at the back of the neck. The combined action of opposing muscles balances the body and keeps it erect.

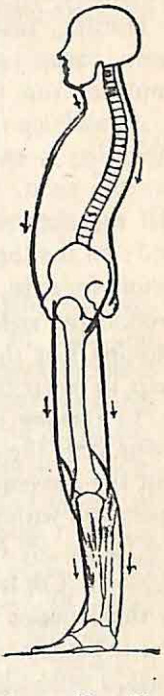


Fig. 32.—*Diagram showing opposing muscles which keep the body erect.*

A baby learning to stand finds considerable difficulty in adjusting the action of all the muscles, but once he has thoroughly learnt it he is able to stand without conscious effort. All the same, the contraction of the muscles is due to the impulses received by them from the central nervous system. A blow on the head or sudden shock to the nervous system not only makes a man senseless but by stopping the nervous impulses from reaching the muscles, causes the latter to relax and the person falls down. The same happens in fainting. Insufficient or improper supply of blood to the brain causes unconsciousness and stoppage of nervous impulses from the brain to the muscles.

In *walking* the body is supported by one foot while the other leg is swung forward. When the advanced foot, say the right, has come in contact with the ground the calf muscles in the other leg (left) contract, raising the body on the toes. The left leg is raised off the ground and swung forward. As the left foot comes in contact with the ground the right leg is raised off and swung forward. In walking fast the arms swing in unison with the legs and help to keep the equilibrium.

In *running* the same alternate movements of the legs occur, only the contractions of the muscles are more violent and the movements more rapid. The heels do not come in contact with the ground and for brief moments both feet are raised off from the ground. In *jumping* both legs act together. Contraction of the muscles of both calves and of the muscles of the thigh takes place simultaneously and the body is swung through the air by the sudden extension of the limbs.

Questions for Examinations

1. What is a joint? Name the different kinds of joints, giving examples.
2. Describe the structures of (a) shoulder joint (b) hip joint (c) ankle joint (d) knee joint.
3. What is a cartilage, and what are its uses ? Name the chief places where it is found.

4. Describe how the erect posture of the human body is maintained.
5. Describe how walking is made possible.
6. Explain the three classes of levers giving examples from the body.

CHAPTER VI

FOOD AND ITS COMPOSITION : VITAMINS

Food.—Our body is a complex machine which generates heat and energy, repairs waste and grows in size and weight. It is a machine which is working every moment of its life. The body is kept warm, the heart keeps beating, and breathing, as well as many other actions and processes, of which we are unconscious, are going on in our body. This is the internal work. The external work consists of all our voluntary acts, such as standing, walking, running, talking, etc. For all these processes it needs food. When absorbed into the system the food is capable of being oxidized, and thus produces heat and energy. During the various life processes the tissues and cells of the body are constantly breaking down and were it not for the fact that the body is a self-repairing machine, it would soon dwindle and die away. Thus the chief uses of food are:—

(1) It is the material which supplies heat and energy.
(2) It makes good the wear and tear of the body.
(3) It supplies material for growth.

All the various functions of food are not performed by each and every article of our diet. Some of the articles of our food produce heat and energy while others replace waste or cause growth. If we analyse the various foodstuffs we find them to consist of a mixture of one or more of the following kinds of substances, called *proximate, principles*, every one of which is essential for life.

Proteins
Mineral Salts
Water
Carbohydrates
Fats
Vitamins

The relative proportions of some of the proximate principles of food-stuffs in certain articles of daily use are given in Fig. 33.

Proteins.—These are complex compounds of carbon, hydrogen, oxygen, nitrogen and sulphur. As they are the only organic food substances which contain nitrogen, they are often called *Nitrogenous* food substances. The common foods in which they are found are—in eggs as *albumin*, in meat as *myosin*, in wheat as *glutenin*, in milk as *casein*, in peas, beans and *dals* as *legumin*.

The use of proteins and mineral salts is to build up the tissues of the body and to repair them when worn out. Hence they are called *tissue* builders and are absolutely necessary for the existence and growth of all animals. If proteins are taken in excess they may give rise to fat in the body and in the absence of sufficient intake of carbohydrates and fats may help in the production of animal heat.

Mineral Salts.—The common salt (sodium chloride) is largely taken with food, not only because it makes the food palatable, but it is also essential to maintain the health of the body. It is contained in all the tissues and is the source of hydrochloric acid found in the digestive juice secreted by the stomach. Calcium is required for the formation of bones and teeth. Phosphates, especially of lime, are required for the building up of bones and iron salts are needed to form hæmoglobin in the blood. Besides these minute quantities of copper and iodine are also necessary. All these salts are present in most kinds of food. These are the second class of building materials and form about one twenty-fifth of the whole body.

Water is present in all the tissues of the body. It serves to dissolve the food when digested and aids in its absorption, keeps the blood fluid and helps in the removal of excretory products from the body. Water is continually separated from the body by all the excretory organs, a person losing on an average 3½ to 5 pints of water per day from the kidneys, lungs, skin and intestines. This is replaced by water in the food. About a pint is obtained from the solid food, the rest being made good by drinking water.

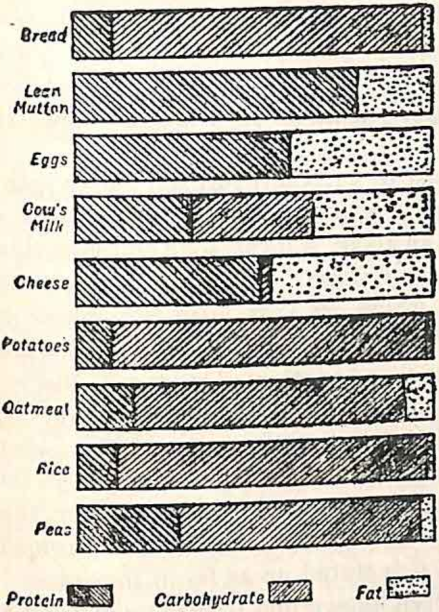


Fig. 33.—*Diagram to show the relative portions of Proteins, Carbohydrates and Fats in common foods.*

(From Cathcart's 'First Book of Physiology and Hygiene'. Macmillan & Co. Ltd. By permission.)

Carbohydrates.—These are compounds of carbon, hydrogen and oxygen, the last two being present in the same proportion as in water. Hence, their name 'Carbohydrates'. The carbohydrates are mainly derived from the vegetable world. Thus we get starch in the grains of all cereals, such as wheat, maize, oats, rice, and in potatoes. Sugar is obtained from the sugar-cane, beetroot and in the juices of various fruits. However, lactose, a kind of sugar is found in milk, and glycogen, a form of starch, exists in the liver.

Carbohydrates are used for the production of energy and the maintenance of animal heat, as well as for the formation of fat in the body. They are cheaper than fats and poor people have to depend largely on them as they are, to some extent, interchangeable with fats, but it has been shown that health cannot be properly maintained if fats are entirely excluded.

Fats.—These consist of carbon, hydrogen and oxygen. Every fat is a compound of a fatty acid and glycerine. When a fat is acted upon by an alkali, it forms soap and glycerine —a process called *saponification.* When fat is broken up into minute globules which are suspended throughout a mixture, the process is known as *emulsification.* Fats are derived from both animal and vegetable kingdoms. Butter, *ghee* and various vegetable oils like mustard oil, coconut oil, are all examples of fats that are used as food. The *use* of *fats* is to procure heat and energy; a given weight of fat produces more heat and energy than the same weight of any other foodstuff. If more fat is taken than is required for heat or energy production, it is stored up as fat in the tissues.

Vitamins.—It has been known that feeding animals only with sufficient quantities of pure proteins, fats, carbohydrates, salts and water does not maintain them in a healthy condition. Such experiments on the feeding of animals led to the discovery of certain substances which must be included in food in order to maintain life. These substances are called *Vitamins* (lit. life-giving substances), and a vitamin free diet gives rise to certain diseases generally known as deficiency diseases and may even cause death. Vitamins are present in all kinds of food and most are destroyed by heat or long keeping. Best source of vitamins is a well balanced diet. Persons who are not healthy or do not eat sufficient vitamins in their food, need extra vitamins by mouth or injections. The following important vitamins have been recognized.

Fat-soluble A-Vitamin, present in certain fats, particularly cod-liver oil, butter, cream, cow's milk, yolk of eggs and in green leaves and certain yellow vegetables and fruits such as carrots, apricots and mangoes. It is however absent from lard and fats of vegetable origin. Vitamin A is the general health vitamin, as it increases the resistance of the body to infection and tones up the whole system. It helps to insure good appetite and digestion, promotes growth and makes for long life. It also helps to prevent infections, particularly of the eyes, throat and respiratory system. Its deficiency causes night blindness, dryness of skin, stunted growth and respiratory diseases. Boiling does not kill it but in drying (e.g. powder milk) it is destroyed. It is manufactured from *carotine* (yellow substance of leafy vegetables and carrots) by the liver and is stored in it.

Water-soluble Vitamin B Complex.—It includes a number of vitamins, all soluble in water and not destroyed by heat. They are very intimately associated in occurence, as well as in function. It is, therefore, doubtful if deficiency of any single Vitamin B factor ever occurs, and, therefore, in treatment all the Vitamins comprising B Complex are given together. But certain symptoms are more marked in deficiency of any particular B Complex factor, and, therefore, that particular B Complex factor is given in larger doses. Some of the Vitamins comprising B Complex have been isolated from natural sources and others prepared synthetically.

Vitamin B_1 (Aneurine Thiamine). It is present in germinating seeds, yolk of eggs, yeast, green vegetables, cereals like wheat and rice, and in fresh peas and beans. In the case of cereals it is present just under the skin and is removed in the process of milling. Vitamin B_1 is the nerve Vitamin. It protects the body from nerve diseases, like Beri Beri. Like Vitamin A, it also acts as a stimulant to the appetite and digestion and as a growth factor.

Vitamin B_2 (Riboflavin) is abundant in milk, eggs, liver, green vegetables, tomatoes and in fruits like apricots and mangoes. Its deficiency results in soreness of angles of the mouth, nose, tongue, lips and eyes.

Vitamin B_6 (Pyridoxine).—It is synthesized in the intestines and its natural sources are cereal grains, legumes, rice, polishings yeast, liver, egg yolk, meat and fish. Signs of its deficiency are inflammation of tongue, mouth and skin near the eyes, nose and mouth.

Its deficiency is associated with deficiency of other members of B Complex. It helps nicotinic acid and in curing Pellagra.

Nicotinic Acid, Niacin and Nicotinamide.—Deficiency signs of these are seen in skin, alimentary canal and nervous system such as in the disease called Pellagra. Hence it is called Pellagra Vitamin.

Panthothenic Acid.—Its deficiency causes retarded growth, sterility, gastro intestinal and nervous disturbances, greying of the hair and burning sensation in hands and feet.

Vitamin B_{12} is present in liver, yeast, cereals and pulses and *Folic Acid* in liver and green vegetables. They are also necessary for blood formation and their deficiency causes pernicious anaemia.

Water-soluble C Vitamin is present in most juicy fruits, especially lemons, oranges, etc. and vegetables, especially cabbage, tomatoes and turnips. Vitamin C is required to promote the normal formation of the teeth, to ensure the health of the teeth and the bones, and to protect the body against scurvy, and help wound healing, blood formation, recovery from illness, and resistance to infection. It is destroyed by heat alkalis and drying.

Fat-soluble D Vitamin is abundant in cod-liver oil and also occurs in milk, butter, ghee, yolk of eggs, liver and fish oils. It has the property of preventing rickets by causing normal bone growth and preventing defective calcification in teeth. It is naturally formed by the action of sun on the skin, and hence the name "Sunshine Vitamin".

Fat-soluble E Vitamin is found in oil contained in the germ of cereals (e.g. wheat) and in certain green leafy vegetables. It has a vital influence on the organs of reproduction, and its absence leads to sterility.

Fat-soluble K Vitamin is found in cabbage, spinach, tomatoes, etc. It helps in coagulation of blood and hence called "Koagulation Vitamin".

Each of these eight distinct kinds of vitamins must be supplied in our diet to keep the body healthy and their absence from our food leads to certain diseases. Rickets is associated with a lack of D Vitamin, Beriberi with a diet poor in B Vitamin and Scurvy with absence of C Vitamin. Scurvy used to be very common amongst sailors on long voyages but is rarely met with now as lime juice is regularly served, whenever there is a shortage of fresh vegetables or fruits. If a reasonably varied diet with fresh vegetables and fruits be taken, there is no need to worry about vitamins as they will have been adequately supplied

Summary of Food-stuffs and their uses in the body

TISSUE-BUILDERS

Proteins, e.g. the albumin of eggs, the casein of milk, the myosin of meat, the glutenin of bread, *form tissues*.	If in excess, may serve as fuel and supply heat and energy.
Salts, e.g. sodium chloride (common salt), the phosphates of lime, soda and potash.	Needed for forming bones and constituents of digestive juices.
Water taken as such and as a component of all solid foods.	Serves to disolve the food-stuffs and to convey them to different tissues; aids in the removal of waste: takes part in tissue formation.

Vitamins in all kinds of fresh animal and vegetable foods.	Necessary to keep the body in a healthy state.

ENERGY-SUPPLIERS

Fats, e.g. the fat of meat, the butter of milk, the oil of seeds *are stored as fats.* *Carbohydrates*, e.g. the starch of bread, the sugar of sugar-cane beet-root, milk, fruits, *are stored as fat or as glycogen in the liver.*	Serve as fuel and are oxidized, thus furnishing heat and energy for muscular work.

Articles of Food.—For the composition of some of the common articles of food the student is referred to the authors' *Elementary Hygiene.*

Essentials of a Good Diet.—A man doing ordinary work needs on an average 100gm. of proteins, 500 gm of carbohydrates, 100 gm of fat and 50 gm of salts every day. There is no article of food except milk which contains these ingredients in the required proportions, and even in the case of milk, these are so highly diluted with water that a man will need a very large quantity to supply the necessary amount of carbohydrates to the body. This difficulty is easily overcome by taking articles of high protein value along with those containing a high percentage of carbohydrates and adding to them a certain amount of *ghee* or butter. Both experience and science tell us that a mixed diet is the most suitable for health and comfort. Thus we eat *dal roti,* or rice and *dal*, or rice and fish, or meat and potatoes, adding to them butter or *ghee*. The diet should vary with the work, weight and age of the individual. A man who works hard needs more proteins to repair the greater waste of his tissues and more fats and carbohydrates to supply energy used in doing the work. Children need a relatively larger proportion of food, particularly proteins, to build weight than adults. Their bodies are growing and they are also more active and restless.

Food should be easily digestible and properly cooked, as it is obvious that indigestible food cannot be assimilated by the body. Thus although peas, beans and *dals* contain a high percentage of proteins the protein is more difficult to digest than that of animal foods like eggs or meat, and much of it passes off in the fæces unused. The vegetable food also contains a large proportion of indigestible cellulose. In general, for the building of muscle protein, the flesh of animals is the best food. The vegetarians also usually take some animal protein, e.g. milk, cheese, or eggs, but a purely vegetarian diet may suffice if rightly selected. Mixtures of seed, nut and leaf proteins may contain all that is essential in the direction.

Questions for Examinations

1. Describe the various proximate principles of food and their uses.
2. Describe the essentials of a good diet.
3. What do you understand by the term "mixed diet" and "perfect diet"?
4. What is the value of green vegetables and fresh fruits in the diet?
5. Why is bread made of wheat-flour and not of rice flour?
6. What are vitamins? Name the important vitamins and their uses.

CHAPTER VIII

THE PROCESSES OF DIGESTION

Digestion is the process of breaking the various foodstuffs into simple products which can find their way into the blood circulation. The digestive system consists of a long tube of varying diameter and of certain glands which pour their juices into it. This tube is called the *Alimentary Canal.* It begins at the mouth, into which cavity is poured the juice from the glands of the mouth. As it passes backwards it spreads into a funnel-shaped cavity called *pharynx.* In the pharynx the openings of the nostrils, the tubes from the ears and the upper end of the wind-pipe are also situated. The tube then narrows into a soft muscular tube about ten inches long, called the food pipe or *Gullet.* This passes down the neck into the chest, lying behind the wind-pipe, pierces the diaphragm and opens into the stomach. The *Stomach* is a large bag lying a little to the left just under the diaphragm. It has two openings, one where the food-pipe ends, the cardiac, and the other where the intestines begin, the pyloric. The alimentary canal narrows again and passes into the *Small Intestine* which is about twenty-two feet in length. The first ten inches of the small intestine, the *Duodenum*, forms a C-shaped loop, in the concavity of which lies an important gland, the *Pancreas.* Into this part open the ducts of the liver and the pancreas. The rest of the small intestine at its end opens into a wide but comparatively short tube known as the *Large Intestine.* It is about six feet long. Just below the junction of the small with the large intestine, the latter has a blind pouch, the *Coecum.* A narrow blind tube, the *Vermiform appendix* about four to six inches long, hangs down from the cæcum. The cæcum occupies the right lower end of the abdomen and the part of the large intestine about it is called the *Colon.* The colon just passes up on the right side, then crosses the abdomen just under the liver and the stomach and lastly descends on the left side. It then passes into a straight tube, the *Rectum*, which opens to the outside by the *Anus.*

The Mouth Cavity.—The mouth cavity is the front spread-out end of the food-pipe. The sides of the cavity are formed by the cheeks, the roof by the palate, the

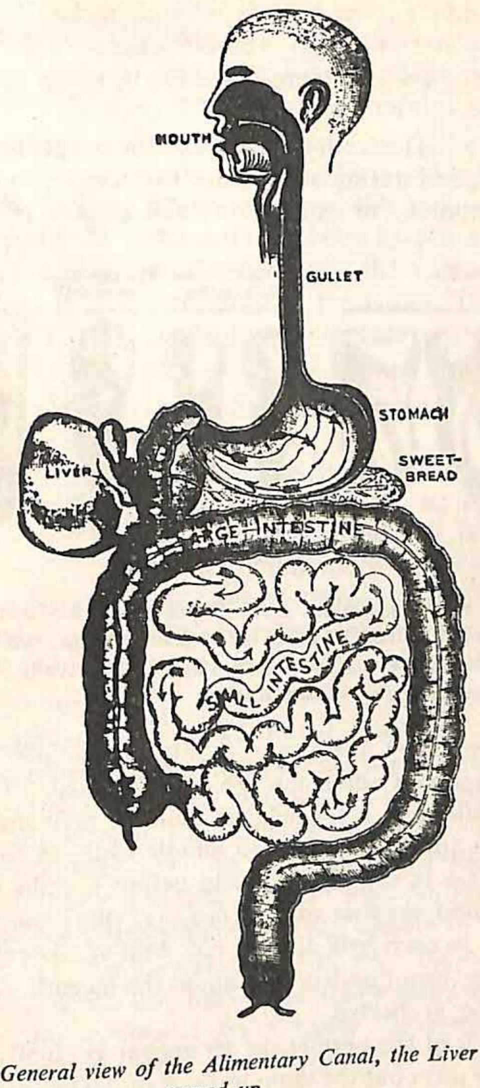


Fig. 34.—*General view of the Alimentary Canal, the Liver being turned up.*

(From Paul's 'Domestic Economy'. By permission.)

floor by the tongue. When closed it is bound in front by the upper and the lower sets of teeth meeting in the middle. The opening at the back of the mouth is known as the throat, on each side of which there is a mass of tissue called the *tonsil.*

The teeth.—The teeth are provided for the proper chewing of food, and during our lifetime two sets are developed, (1) the temporary or milk teeth; and (2) the permanent teeth.

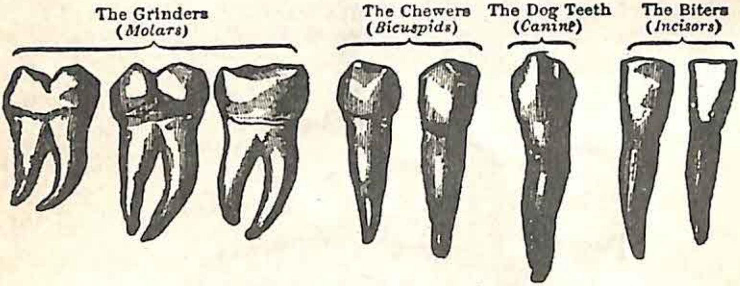


Fig. 35.—*Different kinds of teeth.*

The figure shows the eight teeth found in each half of the upper and the lower jaw. There are two incisors, one canine, two bicuspids and three molars shown in the figure. There are actually four times as many of each in the whole set of teeth.

The temporary teeth are twenty in number. They begin to appear at about the age of six months. They are usually smaller and more delicate than the permanent set. The first to appear are the two middle teeth, in the lower jaw. The set is usually complete before a child is three years old, and consists of two *incisors*, one *canine*, and two *molars* in each half of each jaw, that is, twenty teeth in all. They begin to drop out about the seventh year and are all gone at twelve.

The teeth of the permanent set appear gradually and as they appear push out the temporary teeth. They are thirty-two in number, as, in addition to the teeth corresponding to the temporary set, there are three molars in the upper and the lower jaw on each side.

By the fourteenth year all teeth of the permanent set have appeared except the last four molars. These are called wisdom teeth as they appear after a person is twenty-one years of age.

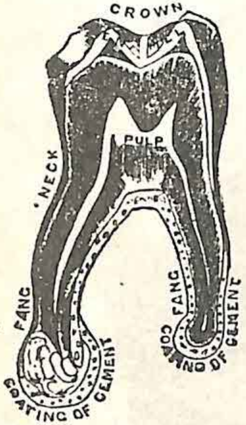


Fig. 36.—*Section of a Tooth.*

Structure of Teeth.—The teeth are set in the jaws; the part of a tooth inside the socket is known as the root or the *fang* and the part above the gum is called the *crown*. The incisors and canines have only one fang each, while the premolars or bicuspids have two, and the molars or tricuspids, three fangs.

A tooth has a central cavity containing blood-vessels, nerves, etc., called the tooth-pulp. Outside it on the crown of the tooth, there is a very hard substance called the *enamel*, while over the fang there is the hard cement substance which fixes the tooth to the socket.

The function of the teeth is to cut, crush and grind the food, the process being known as chewing or mastication. This is effected by the lower jaw working against the upper by means of certain muscles attached to it.

Salivary Glands.—During mastication the food is not only ground but mixed with a fluid called *Saliva* which is secreted by the salivary glands. They are six in all, three on each side. The *parotid gland* (*lit.* near the ear gland) lies in front of the ear, the *sub-maxilary* gland under the lower jaw, the *sublingual* gland under the tongue. The saliva is brought from the glands by ducts which open into the mouth cavity.

Journey of the food.—Let us now see what happens to the food from the moment it is put in the mouth. The food as it enters the mouth (as even the smell, the sight or the thought of food) stimulates the secretion of saliva,

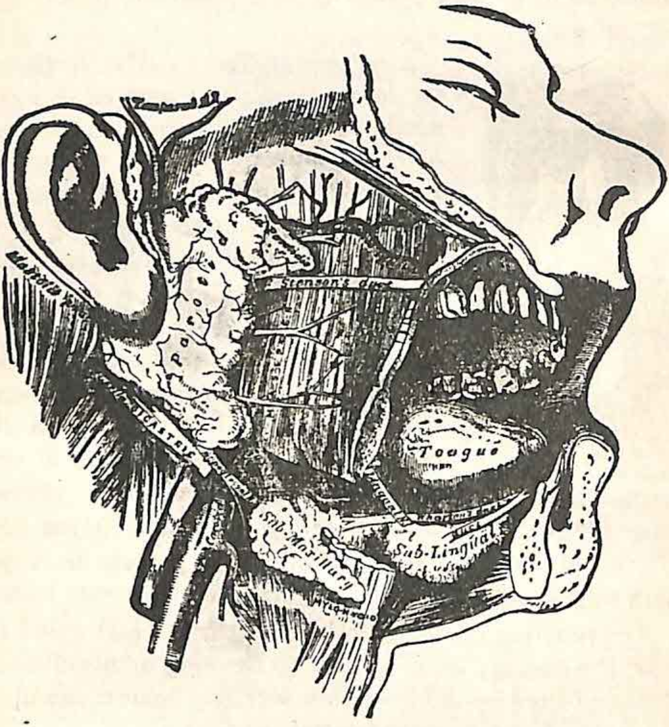


Fig. 37.—*The Salivary Glands*

One side of the lower jaw has been removed and the face dissected, in order to show the salivary glands on the right side.

which is poured into the mouth. The teeth chew the food and break it into small pieces, while the tongue thoroughly mixes the saliva with the food.

The saliva is an alkaline, watery fluid, and contains an active substance (ferment) known as *ptyalin*. *Ferments* are substances which have the power of bringing about profound chemical changes in the substances on which they act, without changing themselves. Thus the ferment ptyalin contained in the saliva changes the starchy matter in the food into a sugar. The insoluble starch is thus partly converted into a soluble and absorbable sugar, while the food is still in the mouth. The longer a morsel of food is chewed in the mouth the better will it get mixed with the saliva. It is important therefore to chew your food well and to keep it long enough in the mouth to get the starch changed into sugar. If you take some cooked rice or a morsel of bread in your mouth, and chew it well, you will find that it becomes slightly sweet in taste. This is because the starch in it has been changed into sugar.

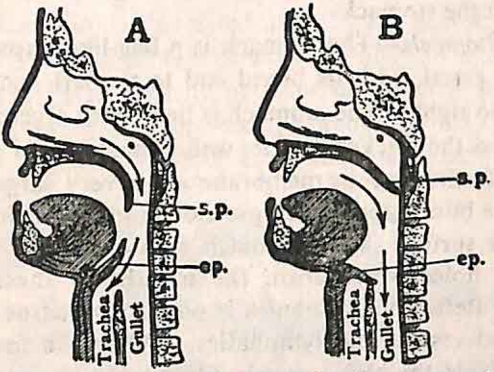


Fig. 38.—*Showing the position of the soft palate (s.p.) and epiglottis (ep.) during (A) breathing and (B) swallowing.*
In A the arrows indicate the passage of air, and in B the passage of the food.

The food after it has been chewed is gathered into a ball or bolus and set down the pharynx into the gullet or food-pipe (Fig. 38, B.). In front of the gullet is situated the wind-pipe (the passage for the air) and the food is prevented from going into that tube, by the tube being drawn up, and the lid-like epiglottis falling down and, for the moment, closing the entrance to it (Fig. 38, B). If a particle of solid food or water should go the wrong way, and get into the wind-pipe, it is expelled by violent coughing.

The food passes down the food-pipe by the action of its muscular walls, which contract above it and push it along. Food does not simply fall down the gullet, but each part of the gullet contracts after the part next above and so squeezes the food along till it passes through the opening and enters the stomach. We shall next consider the structure of that organ and the changes that take place while the food is in the stomach.

The Stomach.—The stomach is a bag-like expansion of the food canal, with its broad end to the left and narrow end to the right. The stomach is lined with mucous membrane and the thickness of its wall is made up of muscular fibres. In the mucous membrane are a very large number of minute blind tubes called gastric glands. On looking at the inner surface of the stomach with a lens, we can see the tiny holes which form the mouths of these gastric glands. Between the tubules is connective tissue containing blood-vessels and lymphatics. When the food enters the stomach, the blood-vessels dilate and bring extra blood to the stomach. Then the cells forming the tubular glands secrete from the surrounding lymph, a colourless liquid called the *gastric juice* (Gk. *gaster*, the stomach). The gastric juice is poured into the cavity of the stomach and mixed with the food by the contractions of the wall of the stomach.

Gastric juice is a colourless, acid liquid, containing water, a minute quantity of salts, a little hydrochloric acid (0.2 per cent, i.e. two parts in 1,000 of the juice), and two ferments called *pepsin* and *rennin*. For some fifteen to twenty minutes after the food enters the stomach, the action of the saliva continues on the starchy portion of the food. The gastric juice has by that time been secreted in sufficient quantity to make the contents of the stomach acid and to stop the action of the ptyalin of the saliva which can act in an alkaline medium only. *Rennin* ferment of the gastric juice coagulates milk and precipitates casein which is then acted upon by the pepsin. The *pepsin* in the presence of hydrochloric acid acts upon the proteins of the food and changes them into simpler substances called peptones, which are soluble and easily diffusible. The gastric juice has no action upon the carbohydrates or the fats of the food. The time taken by the gastric digestion varies with the kind of food, but averages from three to four hours. After food has been thoroughly acted upon by the gastric juice, the stomach would contain starchy portions of the food changed into sugar, starchy portions unchanged, proteins changed into peptones, proteins unchanged, melted fat, indigestible portions of food, all mixed with gastric juice.

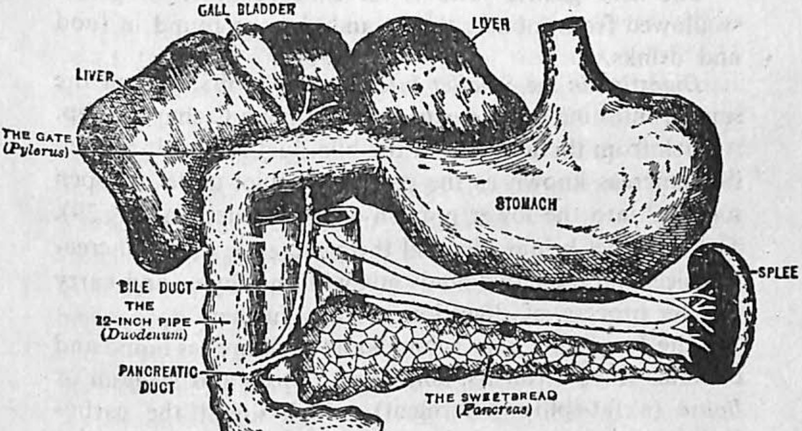


Fig. 39.—*The Stomach, Duodenum, Liver, Gall-bladder, Pancreas, and Spleen.*

The bile duct and the pancreatic duct are seen to open together into the duodenum.

The acid mixture of gastric juice and partly digested food is called *chyme*. Some of the sugar and peptone is absorbed into the blood-vessels of the stomach. The greater part of the chyme passes into the duodenum through the *pylorus*. The opening is surrounded by a band of circular muscles, which remains contracted and prevents food passing from the stomach, until it has been thoroughly mixed with the gastric juice. Finally it relaxes and allows the chyme to pass into the duodenum, where it is acted upon by the juice of the pancreas, the liver and the wall of the small intestine. Besides digestion, important functions of the stomach are the protection of small intestines from injury, especially very hot and very cold foods which are brought to body temperature, chemical irritants such as chillies, alcohol etc. which are diluted, and softening of hard particles of food which have escaped chewing in the mouth.

The acid gastric juice is an efficient killer of germs swallowed from mouth, throat and nose or found in food and drinks.

Digestion in the Smaller Intestine.—The first part of the smaller intestine is the *duodenum*, forming a C-shaped loop. A duck from the liver called the bile duct and a duct from the pancreas known as the pancreatic duct unite to open together into the lower portion of the duodenum (Fig.39). The bile duct brings bile and the pancreatic duct pancreatic juice, and these two fluids mix with the chyme and carry on the process of digestion a stage further.

The *Pancreatic juice* is an alkaline coloureless liquid and contains three ferments, *amylopsin*, *trypsin* and *steapsin* or *lipase* (a fat-splitting ferment), which digest the carbohydrates, proteins and fats respectively. Amylopsin has an action similar to that of ptyalin and changes any starch that has escaped the action of saliva, into sugar. Similarly trypsin acts upon proteins that have not been acted upon by the gastric juice and changes them into peptones, but the important difference is that while pepsin acts in an acid medium trypsin brings about the same action in an alkaline one. The third ferment lipase acts upon fats, splitting fat into fatty acid and glycerine that compose it. The fat-splitting action of lipase is greatly facilitated by the presence of bile. The digestion of the fats is further aided by the formation of soaps. Some of the fatty acid which is set free combines with the alkalies of the intestinal contents to form soap (just as ordinary soaps are formed by the union of fatty acids and alkalies). This soap surrounds the remaining particles of fat and thus makes a still finer emulsion of them, the fine particles remaining suspended in a liquid mass.

The *bile* from the liver has no direct digestive action, but it aids the pancreatic juice in its action on fats. It has important antiseptic properties and keeps down the bacterial contents in the intestines. It also promotes the absorption of the products of digestion.

Intestinal Juice.—The completion of the digestive process is the work of the intestinal juice which is secreted by the glands situated in the mucous membrane of the small intestine. It completes the digestion of starches and proteins, begun by the salivary and carried on by the gastric and pancreatic secretions. Thus the sugar maltose which was formed by the action of ptyalin and amylopsin on starch is changed into simpler sugar glucose by the action of a ferment. The peptones formed by the action of pepsin and trypsin on proteins are converted into simpler end products called *amino-acids*. In addition to these, the intestinal juice contains other ferments which convert the complex cane-sugar and milk sugar into glucose and other simple sugars.

By the time the food goes out of the small intestine it is completely changed into the simple end products that is to say, completely digested. The carbohydrates have all been changed into simpler sugars, the proteins into amino-acids and the fat into fatty acids and glycerine. The intestinal contents are slowly propelled along the gut and at the same time throughly mixed up. The onward movement of the food is effected by means of waves of contraction of the intestines called *peristalsis*. The mixing of food with the digestive juices and bringing them into contact with the intestinal wall, which absorbs digested food and water, is effected by movements called *segmentation* movements, which are sudden local contractions of short length of gut. These can easily be seen in a living animal by means of X-rays, or immediately after death, if the intestines are kept moist.

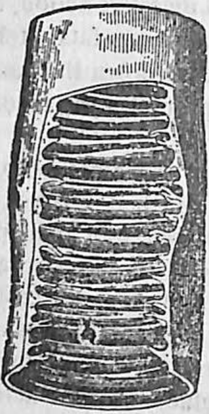


Fig. 40.—*Portion of Small Intestine cut open to show folds of Mucous Membrane.*

(From Quain's 'Anatomy'. By permission.)

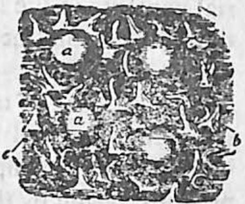


Fig. 41.—*A small portion of the Mucous Membrane of the Small Intestine.*

(From Todd's 'Cyclopædia'. By permission.)
(Magnified 12 diameters)
a. patches surrounded by tubular glands; *b*. villi; *c*. openings of tubular galnds.

Absorption of the Digested Food.—The food that has been digested or changed into a soluble form is then taken into the blood. This taking in, i.e. absorption, chiefly takes place in the small intestine, but to a smaller extent in other parts of the alimentary canal also. The small intestine is lined with mucous membrane, which along the greater part of its length is thrown into circular folds (Fig. 40) which increase the surface from which absoprition can take place. The mucous membrane is further covered with innumerable minute projections, called *vilii* (Fig. 41) rising from it like the pile of velvet. Under the microscope, each villus is seen to be covered with a layer of cells and contains in its interior, blood vessels, lymphatics, nerves, etc. The lymphatics that begin in the villi are called *lacteals* (Fig.42).

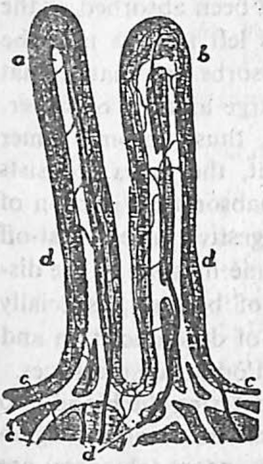


Fig. 42.—*Two villi.*

(From Quain's 'Anatomy'. By permission.) (Magnified 100 diameters) *a*, *b* and *c*, lacteals for absorbing fat; *d* blood vessels which absorb other disgested foodstuffs.

These villi absorb the digested food. The sugars and amino-acids are absorbed by the blood capillaries and the fats by the lacteals. The milky fluid absorbed by the lacteals during digestion is called *Chyle*. The blood capillaries from the various villi unite to form veins, and veins from the stomach, the small and the large intestines unite together to form a large vein called the portal vein, which goes to the liver, on entering which it again breaks up into capillaries. Thus all the carbohydrates and proteins of the food, after digestion and absorption pass through the liver and any excess of carbohydrates in the blood beyond the requirements of the body, is stored up in the liver, by being re-converted into a form of starch known as *glycogen*. The lacteals also unite with one another, to form lymphatics which lead to lymphatic glands, from whence other lymphatics continue to carry the fatty emulsion till they open into a large lymphatic vessel known as the *thoracic duct*. The thoracic duct finally enters into the blood stream at the junction of the two veins at the root of the neck, on the left side of the body.

Most of the digested food having been absorbed in the small intestine, a semi-fluid mass is left to pass into the large bowel. The large intestine absorbs any matter that can still be absorbed as well as a large amount of water. The contents of the large intestine thus become firmer and the part ultimately thrown out, the *fæces*, consists largely of the undigested and the unabsorbable portion of the food, as well as the remains of digestive juices, cast-off cells, bacteria, etc. The large intestine in spite of the disinfecting powers of the bile, is full of bacteria, especially *Bacillus Coli* which set up processes of decomposition and putrefaction and give rise to the bad'odour of the fæces.

The amino-acids are changed on entering the blood into proteins, the fatty acid and glycerine are combined again to form fat droplets while the simple sugars (glucoses) are absorbed as such and are found in the blood stream.

Summary of the Processes of Digestion

IN THE MOUTH:—

Teeth *Saliva*	Chew the food.
Ferment Ptyalin	Changes starch into sugar.

IN THE STOMACH :—

Gastric Juice	
Rennin	Curdles milk.
Pepsin	Changes proteins into peptones.

IN THE DUODENUM:—

Pancreatic Juice	
Amylopsin	Changes starch into sugar.
Trypsin	Changes proteins into peptones.
Steapsin	Splits fat into fatty acid and glycerine.

IN THE SMALL INTESTINE:—

Intestinal Juice

Converts (*a*) Maltose into glucose.
(*b*) Peptones into amino-acids.
(*c*) Cane-sugar and milk sugar into glucose.

Digestion—Absorption.

Questions for Examinations

1. What do you understand by the term "digestion"? Describe briefly the process of digestion.
2. Describe the Alimentary Canal.
3. Describe the part of a tooth. What is meant by "temporary teeth," "permanent teeth"? Name the different kinds of teeth and their functions. What will you do to keep the teeth in good condition?
4. What is a ferment? Name some of those found in the body.
5. Describe the journey of food through the alimentary canal.
6. Write short notes on (*a*) Saliva (*b*) Gastric juice (*c*) Pancreatic juice (*d*) Bile.
7. Describe the course of food after it has been digested in the intestines.
8. What are the functions of the stomach and intestines?

CHAPTER IX

THE LIVER, PANCREAS AND SPLEEN

As seen in the last chapter, closely related with the alimentary canal are two important organs, the liver and the pancreas, secretions from which are brought by special ducts and poured into the duodenum, to help in digestion. We shall now learn some further facts about these, as also about the spleen which is placed to the left of the stomach (Fig. 39).

The Liver.—The liver is the largest gland in the body. It is a reddish brown organ weighing about 3½ lbs. It extends almost across the abdomen, on the right side fitting closely the arch of the diaphragm and extending to the left, slightly overlapping the stomach. A deep depression divides the liver into the right and the left lobe. On the under-surface of the liver is a pear-shaped bag, the *gall bladder*, in which the bile secreted by the liver is collected (Fig. 43) and discharged into the small intestines from time to time.

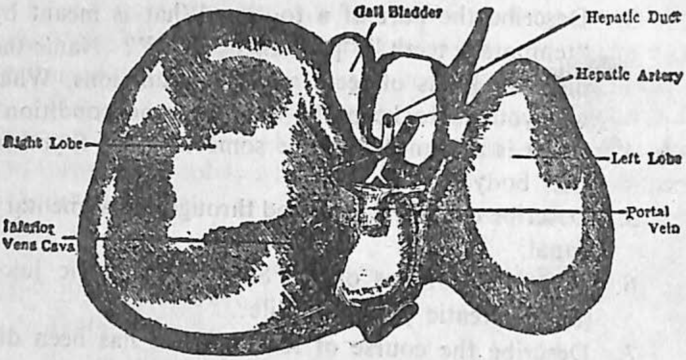


Fig. 43.—*The under surface of the Liver.*

The blood supply of the liver is peculiar. As already stated, the *portal vein* (Fig. 43) coming from the alimentary canal breaks up into capillaries in the liver and these capillaries again unite to form the hepatic veins which open into the *Inferior Vena Cava*. In addition to the portal vein, the liver gets blood from the *hepatic artery* (Fig. 43) which is a branch from the aorta and nourishes the liver cells.

Coming out of the liver is a large tube, the *hepatic duct* (*hepar*, Greek—liver) (Fig. 43), which brings bile from the organ. While passing down it gives a branch the cystic duct which goes to the gall bladder carrying bile to be stored up till actually required for digestion. Further on, the duct is known as the *common bile duct* as it carries bile from the hepatic and cystic ducts and opens into the duodenum along with the duct from the pancreas (see Fig. 39).

Functions of the Liver.—It has been mentioned above that the portal vein brings to the liver blood which after a freshly digested meal, is rich in food materials. Out of these, some of the sugar is converted by the liver into glycogen and stored in it, so that the blood going from the liver does not contain any extra amount of sugar over that usually found in the blood. Between meals the sugar in the blood is used up by the body in producing energy and heat, but the amount of sugar in the blood is kept up by the liver gradually changing the glycogen back into sugar, according to the needs of the body. Other functions of the liver are to secrete bile which aids the digestion of food, acts as an antiseptic and as a laxative; and to destroy any poisonous substances absorbed from the intestines. Yet other functions of the liver are to manufacture vitamin A from the yellow substance carotine, and to store it, to manufacture blood clotting substance called *Heparin* and urea from the products of protein destruction during muscular and glandular activity. This urea goes into the blood and is finally excreted by the kidneys. Liver also destroys worn out red cells, acts as blood reservoir, stores iron, copper and vitamins A, D and B Complex.

The Pancreas.—The pancreas or sweetbread is a long narrow gland. It lies in the bend of the duodenum on the right and extends to the spleen on the left. Its duct opens into the duodenum along with the common bile duct. The pancreas secretes a clear colourless juice which has the important degestive properties described above. In addition to the pancreative juice, the pancreas produces an *internal secretion*, which will be dealt with in the next chapter.

The Spleen.—The spleen is the bluish-red organ situated to the left of the stomach and pancreas (see Fig. 39). It is covered by a special capsule of its own, but its substance is soft and spongy. The soft pulpy susbstance consists of blood corpuscles (both red and white) and some large-branched cells contained in the inter-spaces of fibrous bands. The spleen is well supplied with blood by the splenic artery and the large splenic vein carries the venous blood to the portal vein which goes to the liver.

The functions of the spleen are not fully known. Two functions of the organ are however well known. In the spleen the white corpuscles are formed. Secondly, the old and worn-out red corpuscles gradually break up by being entangled in the spleen pulp and are thus removed from the blood. The spleen is thus known to be 'the birth-place of the white corpuscles and the graveyard of the red'. In many ineffective diseases the spleen is enlarged and it seems to protect the body by removing micro-organisms such as in typhoid fever from the blood and destroying the poisons formed by them. After continued attacks of malarial fever the spleen is greatly enlarged but comes back to the normal size if the patient is carefully treated. Being spongy in character the spleen is able to retain a large amount of blood, and thus acts as a reservoir, and by its regular contractions receives or forces out blood according to the needs of the body, as in hæmorrhage, exercise, etc. Spleen also produces anti-toxins, and acts as a storage for iron fats, etc. Spleen, however, is not essential to live and one can live normally after its removal due to injury or disease.

Questions for Examinations

1. Give a short description of Liver, Spleen, Bile, Villus, Lymph, Chyle, Chyme, and their functions.

2. Give the functions of the liver.
3. What is *pancreas* and what are its functions?
4. What is portal Vein?

CHAPTER X

THE DUCTLESS OR ENDOCRINE GLANDS

The Ductless Glands.—The ductless glands are organs which have some resemblance to a gland, but have no duct to pour out their secretion. They are also known as endocrine glands. The products of their activity directly pass into the blood passing through those glands and are on that account called *internal secretions* or *harmones.* The important ductless glands are the pituitary, the thyroids, the para thyroids, the pancreas, the supra-renals, the ovaries and the Testes. The internal secretions of various glands stimulate to activity and regulate the functions of distant organs to which they are carried through the blood stream and thus secure the harmonious co-operation of one organ with another. For example, as soon as the food enters the duodenum, certain cells in its wall secrete a particular substance—not into the digestive tube, but into the blood. The blood carries it all over the body, but when it reaches the pancreas it awakens that organ and makes it produce the pancreatic juice. The internal secretions may therefore be aptly described as the chemical messengers of the body.

The Pituitary Gland.—It is a small, reddish grey body hanging down from the middle of the lower surface of the brain. It is made up of two distinct parts each of which produces its own secretion. One of the internal secretions of the front part regulates (a) the growth and development of the body and its over-activity leads to increased stature or excessive growth of hands, feet and part of the skull etc. When the secretion is deficient children do not grow up properly and remain undersized; (b) regulates milk secretion in mammals; (c) regulates fat, protein and sugar metabolism. The other secretions of the front part regulates the activities of the thyroid, supra-renals and sex organs.

The hinder part produces two internal secretions (a) *pitressin* or *vas operession*, which strengthens movement of the bowels, tones up the blood vessels, and diminishes the amount of urine in diabetes insipidus, in which a large amount of clear urine without sugar is passed; and (b) *oxytoxin* which causes contraction of the pregnant uterus and expel milk contained in the breasts.

The Thyroid Gland.—The thyroid gland is a brownish red body situated in front of the neck, just below and on each side of the larynx. Its abnormal increase in size is known as goitre. Its internal secretion, known as *thyroxine* is very rich in iodine, and its effect is to increase the chemical activity (metabolism) and growth of all parts of the body. A deficiency of the secretion leads to sluggishness and undergrowth. The proper growth of the body and the full activity of the mind are possible only if thyroid keeps forming its daily dose of the hormone. The thyroid gland is rich in iodine which is essential for its secretion. An increase of thyroxine from over-activity of thyroid, causes increased heart rate and respiration, general restlessness, fine tremors, and sugar in the urine.

The Parathyroids.—These are four small glands behind the thyroid. Their secretion, *parathormone*, regulates calcium metabolism.

The Pancreas.—In addition to secreting the pancreatic juice, the pancreas produces an internal secretion which is absorbed into the blood stream. This internal secretion called insulin helps the tissues to burn up and utilise the carbohydrates, and if the internal secretion is absent or deficient, the carbohydrates are not burnt properly, but collect in the blood, and sugar appears in the urine. This appearance of sugar in the urine due to the deficiency of insulin is called *Diabetes*. Insulin is prepared by special groups of cells called the Islets of Longerhaus which are scattered throughout the pancreas.

The Supra-renals.—The supra-renal bodies or adrenals are two small yellowish glands lying just above the kidneys. Each consists of two parts, the outer *cortex* and the inner *medulla*. The cortex produces internal secretions which (a) influence sex organs both in the male and in the female; (b) maintain normal blood volume by controlling excretion of salt and water in the kidneys; (c) generally influence tissue and liver functions and sugar metabolism; and (d) it is rich in Vitamin C. The internal secretion of the inner part or the medulla called *adrenalin* is used in calling forth the resources of the body in an emergency, as in a fight or escape, from an enemy. When faced with danger, the nervous system sends a message to these glands to promptly pour their secretion into the blood stream. As the secretion is carried round the body, it affects different organs in different ways. The heart begins to beat faster, the sweet glands are stimulated, so that the body may be kept cool, the movements of digestive organs are slowed and their blood vessels contracted, the liver is made to part with its stored glycogen so that the muscles may have greater supply of fuel, the hairs stand on end, the eyes bulge and the pupils are dilated so that the individual may have a terrifying look. The secretion acts as a chemical whip, to awaken all the organs to increased activity, to meet the common danger.

The Sex Glands, the *ovaries* in the female and the *testes* in the male, produce internal *secretions*, which, as already mentioned above, are regulated by the anterior pituitary hormones. During childhood, small amounts of these hormones help gradual development, but at puberty the output of these hormones increases, causing rapid development of sex characteristics.

Questions for Examinations

1. What do you understand by "Internal Secretions"? Give examples.
2. What are ductless glands? Enumerate the chief ones.
3. Give briefly the functions of (a) thyroid gland; (b) pituitary gland; (c) supra-renal bodies. Where are these situated?

CHAPTER XI

THE BLOOD

The Blood.—Blood is the fluid which brings oxygen and nourishment to all parts of the body and removes the waste products formed in them. It consists of an almost colourless fluid called plasma in which float myriads of small bodies called *corpuscles*. Under the microscope these corpuscles are seen to be of three kinds: (1) the *red corpuscles*, (2) the *white* or *colourless corpuscles*, and (3) *blood platelets*.

The Red Corpuscles are minute circular discs, both surfaces of which are concave. They have no nuclei. Each cubic m.m. of circulatingblood contains five millions of red blood cells. They are so small that if placed flat, edge to edge, about ten million would be required to cover a square inch. When examined under the microscope they are individually seen to be pale yellow in colour, but they are so numerous, that they give to the blood its red appearance (Fig. 44). In structure the red corpuscles resemble a sponge, being made of an elastic envelope containing a red pigment called *hæmoglobin*. Hæmoglobin has a great attraction for oxygen with which it readily combines, as in the lungs to form *oxyhæmoglobin*, which is bright red in colour. But this union is very feeble and the oxygen is readily set free in the tissues when the blood circulates through them. Thus the function of the red blood corpuscles is to carry oxygen from the lungs to the tissues. In the developing young one, before birth, these cells are formed in the liver and the spleen while in adult life they are formed in the bone marrow.

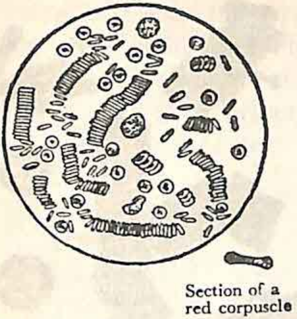


Fig. 44—*Blood as seen under the microscope*.
Red corpuscles are seen in piles and singly; also three white corpuscles.

The *White Corpuscles* are colourless and irregular in shape and have nuclei. They are also called *leucocytes*. They are far less numerous than the red corpuscles being in the ratio of 1 to 500 to 600. Each cubic m.m. of blood contains about 7000 white blood cells. They are constantly changing their shapes and thus resemble a minute microscopical animal *amœba* found in pound water. Consequently their movements are described as *amœboid movements*. By means of these movements they are capable of moving from one place to another and even of getting out through the thin walls of the smallest blood vessles. They are also able to take up particles of foreign matter such as disease germs and thus act as guards of the body. In cases of infection with disease germs, the white corpuscles gather round the germs and try to eat them up. They are formed in the bone marrow, lymph glands and other lymphoid tissue in the spleen, intestines, etc.

The *Blood Platelets* are spherical or oval non-nucleated discs, about one-third the size of red cells. Their proportion to red cells is one in eighteen. They are produced in the bone marrow and after a few days of life they die in the spleen. They play an important part in the arrest of bleeding and the healing of wounds.

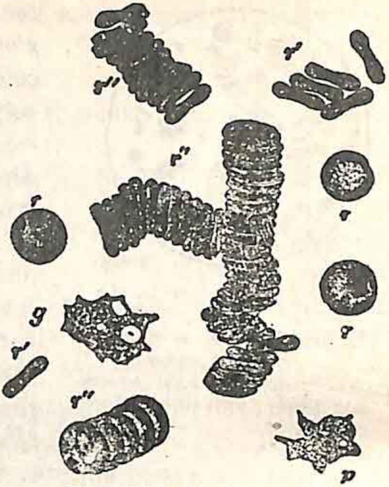


Fig. 45.—*Blood Corpucles, as seen under a microscope, more highly magnified.*

(From Quain's 'Anatomy'. By permission.)

The *plasma* is a transparent, pale yellowish fluid in which the corpuscles float. It consists of 90 per cent water and 10 per cent of solids in solution. The solids are various proteins, inorganic salts, of which sodium chloride is the chief and a small quantity of fat. Besides these, the blood also contains certain gases, chiefly carbon dioxide and oxygen. The former is chiefly in the plasma, while the latter as mentioned above, is carried in loose chemical combination with the hæmoglobin of the red corpuscles. Thus all the substances from which the different tissues of the body are built up, are contained in the blood.

Clotting of Blood.—When blood is withdrawn from the body and allowed to stand still for some time, it becomes semi-solid, i.e. coagulates. After some little time the *clot* begins to shrink and compress out a pale yellow fluid called *Serum*. The coagulatioon is due to the change of a soluble substance, *fibrinogen* dissolved in the plasma of the living blood into a thread-like solid called *fibrin*, which takes place only after the blood is shed. The fibrin entangles in its meshes the corpuscles and forms the clot. The clotting of the blood at the site of a wound plugs the opening in the blood-vessel and thus serves the important purpose of preventing further bleeding. The clotting of blood is hastened by contact with injured tissue or with a foreign substance such as cotton wool, by heat and by addition of certain substances called coagulants, such as calcium, diluted viper venom, vitamin K, and locally, by application of cold, which acts by contracting blood vessels. Outside the body clotting is prevented by refrigeration and by addition of anti-coagulants such as citrates, oxalates, herudin obtained from head of leech etc.

Fig. 46.—*Blood clot floating in serum,*

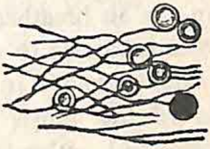


Fig. 47.—*Threads of fibrin entangling corpuscles, as seen under the microscope.*

The process of clotting may be represented as follows:—

Living blood consists of		Coagulated blood.	
Corpuscles (red and white)		Corpuscles	Clot
Plasma	(Fibringen (in solution)	Fibrin	
	Serum	Serum	

Functions of the Blood.—The blood circulates in the body in order to take nourishment to all parts of the body and to remove waste matters produced by the activity of the different parts, and secondly, to supply oxygen to all the tissues and to remove the carbon dioxide from them. The reader is aware that the blood receives fresh supplies of nutrient substances from the alimentary canal as the food is digested and absorbed. These nutrient substances must be carried to all parts of the body to enable the tissues to choose and pick up what they need for their repair and growth. In return the tissues burden the blood with their waste products which it must carry till it can get rid of them on passing through an organ like the kidney or skin (*excretion*). Similarly, the blood obtains fresh supplies of oxgygen from the air breathed in, when it goes to the lungs. This oxygen is carried to all the tissues of the body and carbon dioxide is brought in return from them. When the blood goes to the lungs, it exchanges this carbon dioxide (*respiration*). Blood also carries hormones of the ductless glands to the various organs. It also regulates temperature by evaporation from the skin and by contraction and dilation of skin capillaries by cold and heat. In addition to these the important functions of red and white blood cells and blood platelets have already been described and need not be repeated here.

Blood Transfusion —If blood is lost by severe bleeding or some other cause, such as worms in the intestines which suck blood and cause severe anaemia, it can be replaced from another person. This is called *blood transfusion*. Before blood can be transferred, it should be typed, that is blood of the patient must be matched with that of the donor to see that it is not incompatible. If a small amount of blood of the patient is mixed with the blood of the donor, if it is incompatible, it will clot. There are four common types of blood: A, B, AB and O. Type AB is the universal recipient and type O is the universal donor. The blood is stored in hospitals ready for emergencies and labelled according to the stored blood type. Even then blood should be cross-matched before transfusing. There are other blood groups which can be determined by similar agglutination reactions. Most important of these is the

Rh type when blood containing the Rh factor is mixed with the blood without the Rh factor, agglutination and hemolysis may occur. Therefore all blood transfusions should be Rh typed.

Questions for Examinations

1. Give a short account of the blood.
2. What is the difference between blood plasma and serum; between arterial blood and venous blood?
3. What is coagulation of the blood and what purpose does it serve?
4. How can coagulation of blood be hastened and slowed?
5. Why does not blood clot in living blood vessels?
6. What are the functions of the blood?
7. What are the functions of blood plasma, red and white blood corpuscles and blood platelets?

CHAPTER XII

THE CIRCULATION OF BLOOD: BLOOD PRESSURE

IN THE first chapter we have already learnt that the circulatory system consisting of *heart* and *blood-vessels* is concerned with carrying the blood to all parts of the body and bringing it back.

The Heart.—The heart is a hollow muscular organ which pumps, by its contraction, the blood into the blood-vessels. It is situated about the middle of the chest cavity, just above the diaphragm and between the two lungs. It is cone-shaped with its base pointing upwards and its apex directed downwards and to the left. In size it is about equal to one's closed fist. It is enclosed by a thin double-layered membranous bag, the *pericardium*, which secretes a little fluid, just sufficient to keep the heart moist and facilitate its movements.

Internally the heart is divided by a vertical septum into right and left halves which do not communicate with each other. Each half consists of two chambers, the upper auricle and the lower ventricle. The auricles are small and thin-walled, while the ventricles are large and thick-walled. The right side of the heart can be easily distinguished from the left by the walls of its ventricles being thinner as com-

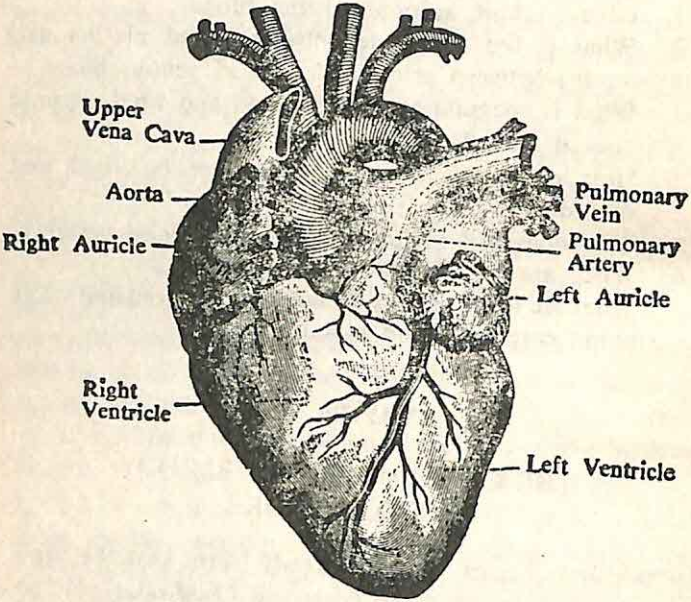
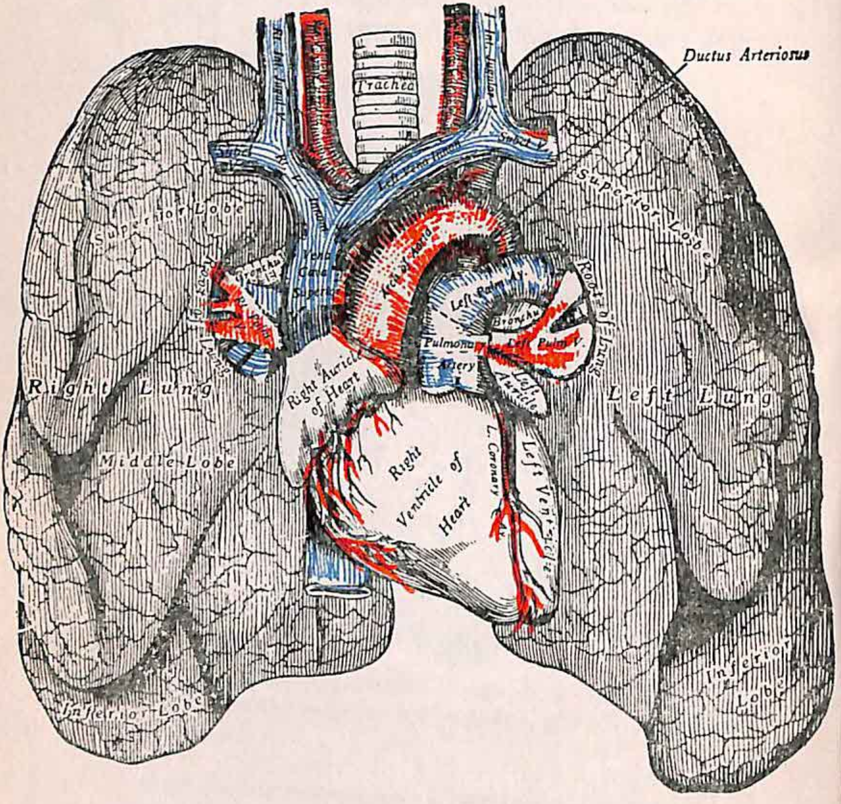


Fig. 49—*The Heart as seen from the front.*
On the front surface in the groove are the artery and vein for the heart itself.

Fig. 48—*Front view of heart and lungs. See coloured plate opposite.* Vessels carrying arterial blood are shown red, those carrying venous blood blue.


Ductus Arteriosus
Rt. Int. Jugular V.
Trachea
Lt. Int. Jugular
Subcl. V.
Subcl.
Left Innom.
Rt. Innom.
Superior Lobe
Superior Lobe
Bronchus
Root of Lung
Vena Cava Superior
Arch of Aorta
Left Pulm. Ar.
Bronchus
Pulmonary Artery
Left Pulm. V.
Root of Lung
Right Lung
Right Auricle of Heart
Left Auricle
Left Lung
Middle Lobe
Right Ventricle of Heart
L. Coronary
Left Ventricle
Inferior Lobe
Inferior Lobe

pared with those of the left ventricle which are thicker and firmer.

Each auricle communicates with the ventricle of its own side through an opening called the auriculo-ventricular opening. On each side, the opening is guarded by a valve which only allows blood to pass from the auricle to the

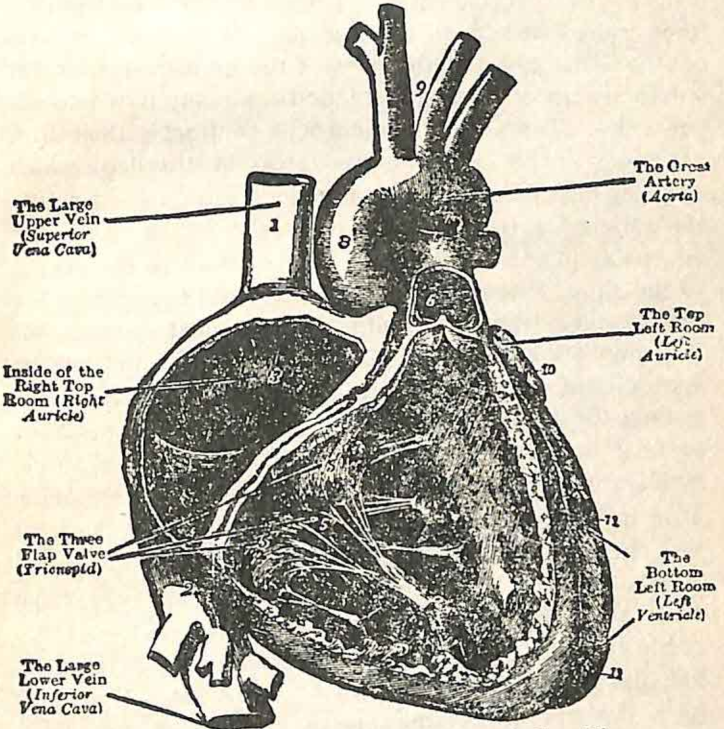

9
The Great Artery (*Aorta*)
The Large Upper Vein (*Superior Vena Cava*)
1
8
6
The Top Left Room (*Left Auricle*)
10
Inside of the Right Top Room (*Right Auricle*)
3
5
12
The Three Flap Valve (*Tricuspid*)
The Bottom Left Room (*Left Ventricle*)
The Large Lower Vein (*Inferior Vena Cava*)
11

Fig. 50.—*Interior of the Right Auricle and Ventricle, their front wall being removed.*

(From Quain's 'Anatomy'. By permission.)

I, superior vena cava; 2, inferior vena cava; 3., interior of the right auricle; 4, semilunar valves at the commencement of the pulmonary artery; 4′, one of the papillary muscles; 5, 5′, 5″, cusps of the tricuspid valve; 9, pulmonary artery; 7, 8, and 9, the aorta and its branches; 10, left auricle; 11 left ventricle.

ventricle, but not in the reverse direction. The valve on the right side has got three flaps and is known as the *tricuspid valve* while that on the left side has only two flaps and is called the *bicuspid valve* or from its resemblance to the cap of a bishop, the *mitral valve*. From the edges of these caps a number of tendinous cords (*chorde tendine*) run to the walls of the ventricle and are attached to muscular projections called the *papillary muscles*. When the auricles contract, the edges of the flaps of the auriculo-ventricular valves are pressed apart, and blood can easily flow into the ventricles. Next, when the ventricles contract in their turn, the blood inside the ventricles forces up the flaps which are now raised like a canopy and blood cannot go back into the auricles, as the flaps meet each other in the centre and effectively guard the opening. There would be the danger of the flaps floating up into the auricle and thus permitting the passage of the blood, but this is prevented by the papillary muscles sharing the contraction of the wall of the ventricle, of which indeed they are projections, and thus pulling the tendinous cords and not permitting the flaps to float up into the auricle. The blood in the ventricle is thus forced to go into the respective blood-vessels which arise from them, viz, the pulmonary artery from the right and the aorta from the left ventricle.

The openings leading to the pulmonary artery and the aorta are guarded by valves of a different sort. At the commencement of each of these three tubes are three pockets bulging inwards from the wall of the artery. Owing to their resemblance to half moons, the valves are called *semilunar valves*. When the contraction of the right and left ventricles forces blood into the pulmonary artery and the aorta respectively, these valves, permit the blood to enter these arteries, as the pockets are pressed against the wall of the artery. As the ventricles begin to dilate, the blood would tend to flow back into them, but the pockets now get filled with blood, and bulging inwards and meeting in the centre, effectively close the opening of the pulmonary artery or the aorta as the case may be.

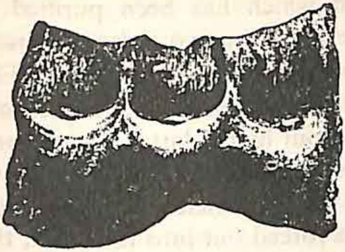


Fig. 51—*The Semilunar Valves at the beginning of the pulmonary artery, artery the tube being cut and laid open.*
(From Todd's 'Cyclopædia.'
By permission.),

Action of the Heart.—In examining the heart, the large blood-vessels entering and leaving the different chambers have also been referred to. It is necessary to note that a blood-vessel leaving the heart and carrying the blood away from it is called an *artery*, and a blood-vessel returning blood to the heart a *vein*. The impure blood from all parts of the body is returned to the right auricle by two large veins, that from the head and upper limbs by the *superior vena cava*

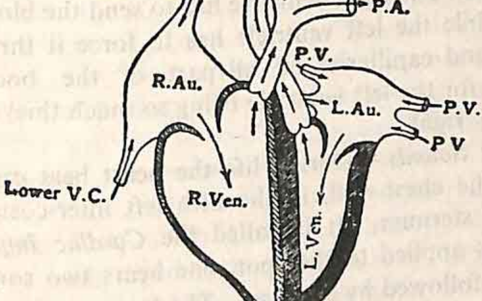


Fig. 52.—*Diagrammatic section of the Heart to show its chambers and the direction of blood-flow through them.*
The arrows indicate the direction.

and from the lower parts of the body by the *inferior vena cava* (Fig. 52). The blood which has been purified or oxygenated in the lung is returned by two *pulmonary veins* from each lung, all four opening into the left auricle (Fig. 52). The impure blood in the right auricle is squeezed into the right ventricle and forced out by the latter into the *pulmonary artery*, which divides into two branches for the two lungs. The pure blood from the left auricle goes into the left ventricle, and by the latter is forced out into the *aorta*, the branches of which carry the blood to all parts of the body, for their nourishment.

The heart beats in an adult about 72 times per minute, but the rate varies according to the position of the body, being faster in walking than sitting and is increased by exercises excitement, fever, etc. The beat consists of a contraction of the auricles followed by a contraction of the ventricles, after which there is a pause during which the whole heart dilates. The contraction is called *systole* and dilation *diastole*. Both auricles contract together and similarly both ventricles, so that blood is entering, or leaving the chambers on both sides at the same time. Auricles are thin-walled as they have only to force the blood into the ventricles. The right ventricle has to send the blood to the lungs, while the left ventricle has to force it through the arteries and capillaries of all parts of the body. This accounts for the left ventricle being so much thicker-walled than the right.

Heart Sounds.—During life the heart beat can be felt against the chest-wall, in the fifth left inter-costal space, near the sternum. It is called the *Cardiac Impulse*. If the ear is applied to the spot, one hears two sounds like *lub*, *dup*, followed by a pause. The first sound is dull and is caused by ventricular systole, while the second sound is short and sharp and is caused by the closing of the two semilunar valves. These sounds are called *Heart Sounds*. You must have seen doctors listening to these sounds through a stethoscope, to detect any changes due to disease.

Automaticity of Heart and regulation of frequency and force of Heart beats.—It is important to remember that unlike other muscles, the heart muscle possesses some inherent properties, the chief ones being its power of originating rhythmic contractions, and conducting waves of contractions from fibre to fibre. Normally, these contractions start in the upper part of the auricles and gradually spread down to the ventricles. In a recently killed frog, the heart keeps on beating for some time, even when removed from the body showing that the power to contract and relax is inherent in the heart muscle.

In the living body this property of automatic movements is controlled by the central nervous system. As you will learn in subsequent chapters the rate of heart contractions is controlled by the *Vagus* and the *Sympathetic* nerves, some of whose branches are supplied to the heart. The excitation of the vagus or tenth cranial nerve slows the heart while its inhibition makes the heart beat faster. On the other hand, excitation of the sympathetic makes the heart beat faster and its inhibition slows the heart. As is well known, strong emotions, like sudden fright make the heart beat slower or faster, the former is due to central stimulation of the vagus, and the latter to the stimulation of sympathetic nerve endings in the heart by the internal secretion of the medulla of the supra-renals, as already mentioned in the chapter on hormones.

The Pulse.—With each contraction the left ventricle forces a fresh quantity of blood into the already distended arteries which being elastic are stretched more and then gradually contract to push the stream of blood onwards. The expansion of the arteries starts at the root of the aorta and proceeds as a wave along the whole arterial system. This wave of expansion is called the pulse. The pulse can be readily felt where an artery is near the surface of the body, and passes over some hard structure, e.g. in the radial artery at the wrist. There is no pulse in the capillaries nor in the veins as the jerky flow of blood in the arteries is converted into a steady continuous flow in the capillaries and the veins. It is for this reason that a cut artery spurts out blood in jerks, while in the case of a vein being cut the blood is seen to flow out in a steady stream.

The frequency of the heart beat and so of the pulse, varies with the age, sex and activity of the individual. During the first year of life, it is 120 per minute and then gradually decreases to the adult standard. It is slightly quicker in women and small-sized individuals than in men and tall persons.

Blood Pressure.—As stated above, with each beat of the heart, blood is pushed into the already filled arteries, stretching their elastic walls. This pressure of the blood against the walls of the arteries is called *Blood Pressure.* It is during the systole (contraction) of the heart that blood pressure is highest, and is called *systolic* pressure, while during the diastole (relaxation) of the heart the blood pressure is lowest, and is called *diastolic* pressure. Thus it will be seen that blood pressure is a normal occurrence in all men. It is measured by an instrument called Blood Pressure Apparatus which registers the pressure by a needle travelling round a dial or by the height of column of mercury in a glass tube, and is expressed in millimeters of mercury. In an adult the normal systolic blood pressure is between 110 and 130, and diastolic blood pressure between 70 and 90.

High blood pressure is a disease and may be very dangerous if very high blood pressure is caused by the *force* of the heart pumping the blood through the arteries and the *resistance* offered to this flow by the arterial walls. The rise in blood pressure is the result of alteration of both these causes. Increase in the rate and force of heart beat by emotion, anger, worry, over-anxiety, to take things too seriously or continued mental and emotional strain or chronic alcoholism cause high blood pressure. This is also caused by increase in the volume of blood by overeating and overdrinking and by contraction of the smaller arteries in old age, excessive smoking and kidney disease which increase resistance to the flow of blood.

Common symptoms of high blood pressure are headache, giddiness, sleeplessness, palpitation, mental irritation, etc. By proper and early treatment high blood pressure may come down to normal.

The best treatment is to avoid the causes mentioned above, to take sufficient rest mentally and physically, with limitation of diet to vegetables, fruits and milk, avoiding tea, coffee, wines, smoking and cold or very hot baths. If these simple measures fail to reduce blood pressure, a qualified doctor should be consulted.

Low blood pressure is the result of heart weakness, lack of blood from disease or bleeding, under-nourishment, debility etc, and its treatment is the treatment of its causes.

The blood continues to run in a system of closed tubes. The biggest artery called the *aorta* gives off branches to all parts and organs of the body. Each artery on entering an organ breaks up into smaller and smaller branches till finally a network is formed of extremely minute microscopic tubes called the *capillaries*. The walls of these capillaries are so exceedingly thin that some of the liquid portion of the blood (called *lymph*) can ooze out through them to feed the cells surrounding the capillaries. The cells of every tissue are bathed in lymph, from which they take up their nourishment and into which they throw their waste products. Oxygen is also handed across the thin walls of the capillaries, from the red blood corpuscles carrying it to the tissues surrounding the capillaries and carbon dioxide is passed back into the blood. Much of the lymph that passes out of the capillaries returns again, after undergoing the changes mentioned above, into the capillaries. The capillaries unite to form a vein and the blood that has undergone the changes in passing through the capillaries may now be described as venous.

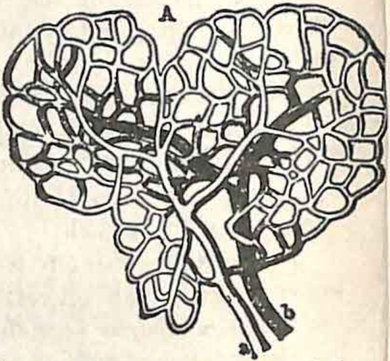
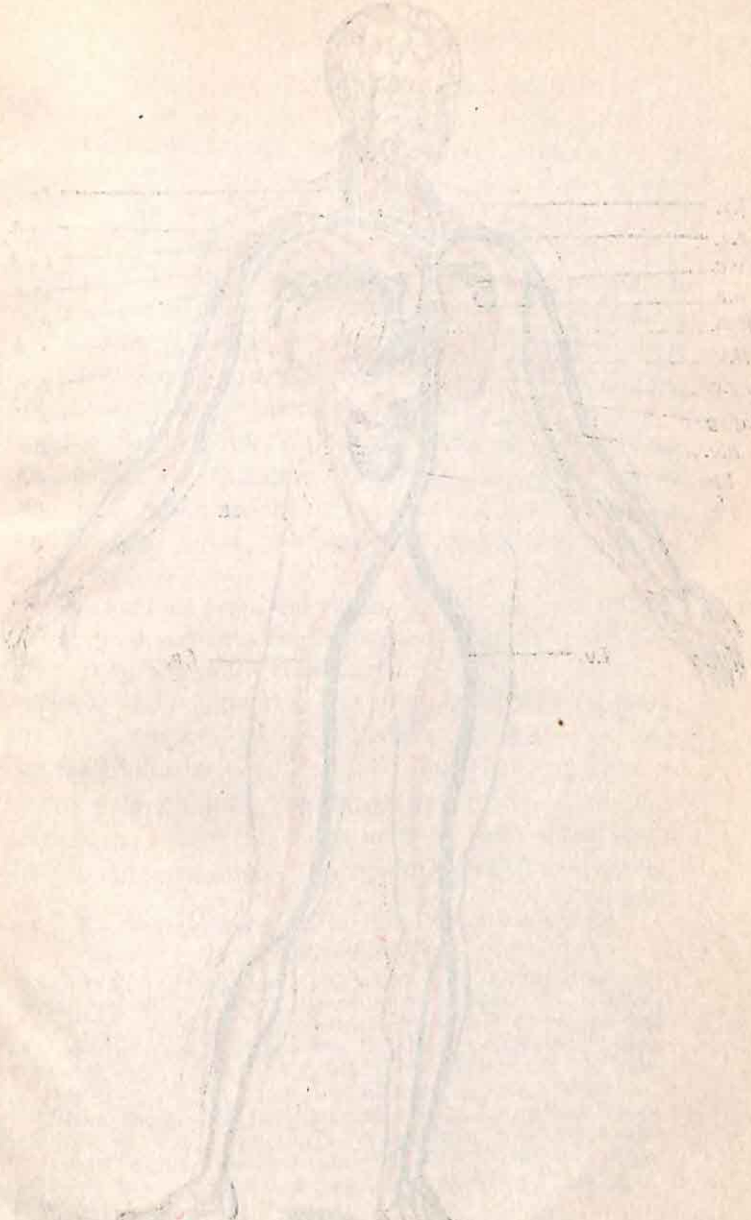
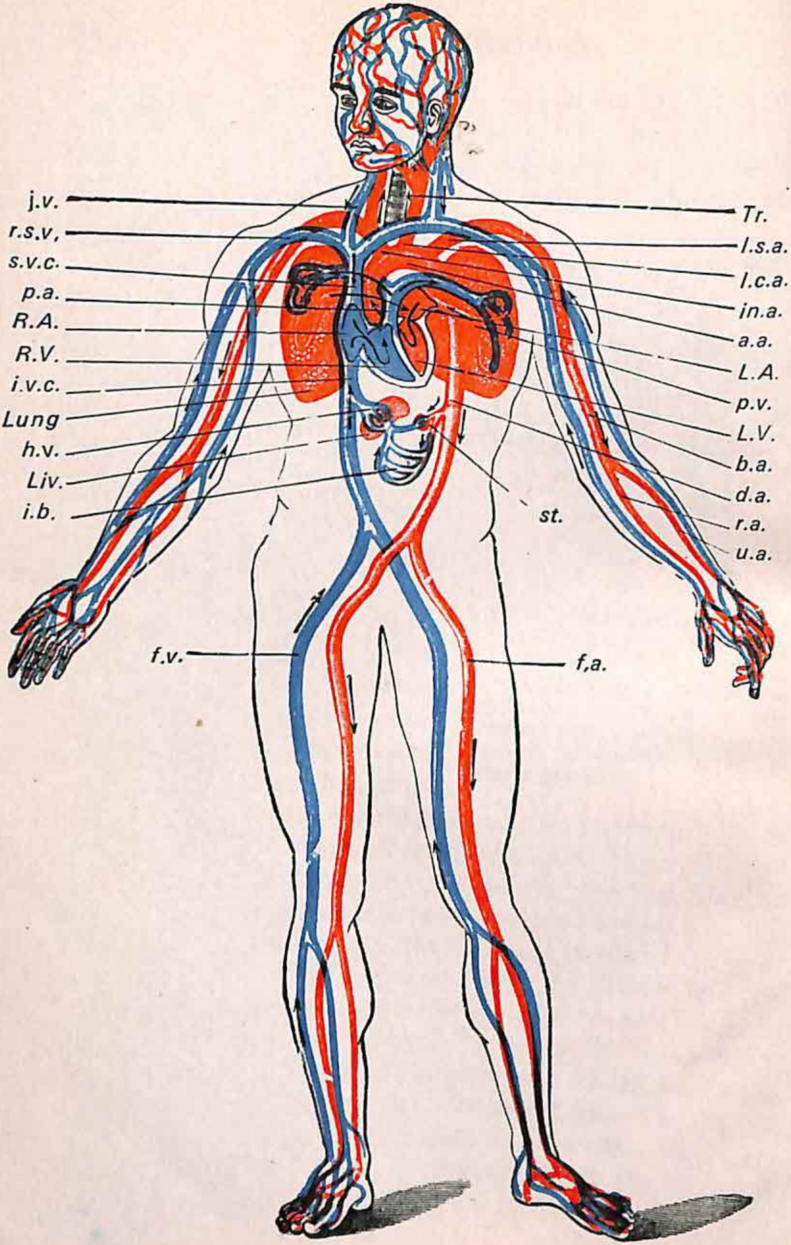


Fig. 53.—*Magnified view of the Capillary network surrounding a mass of cells.*

a, small entering artery; A, the capillaries; *b*, the small vein coming away. Illustrates the changes of arterial blood to venous blood.

We are now in a position to follow the blood in its complete round in the body, starting at the left ventricle and returning to the same chamber again. By the contraction of the left ventricle the pure blood in that chamber is pumped into the aorta, which arches to the left and runs down close to the vertebral column, through the thorax and the abdomen. Three large arteries are given off from the arch of the aorta (Figs. 48 and 54). The first of these divides into two, viz, the *right carotid artery* which runs upwards through the neck to supply the right side of the neck and head and the *right subclavian artery* which passes under the clavicle into the arm, dividing at the elbow into *radial* and *ulnar arteries* (the pulse is usually examined by feeling the radial artery at the wrist). The *left carotid artery* for the left side of the neck and head, and the *left subclavian artery* for the left arm, arise directly from the arch of the aorta. The aorta gives off various arteries to the muscles of the thorax as also to the gullet and the tissues of the lungs.




j.v.
r.s.v,
s.v.c.
p.a.
R.A.
R.V.
i.v.c.
Lung
h.v.
Liv.
i.b.
Tr.
l.s.a.
l.c.a.
in.a.
a.a.
L.A.
p.v.
L.V.
b.a.
d.a.
r.a.
u.a.
st.
f.v.
f,a.

The aorta pierces the diaphragm and passes down the abdomen. In the abdomen it supplies branches to the diaphragm and to the various organs contained in the abdomen. One short branch divides into three for the stomach, the spleen and the liver. Two arteries supply blood to the mesenteries and the different parts of the intestines. The arteries supplying the stomach and the intestines are represented only in a diagrammatic manner in the colour plate facing this page. The venous blood from these parts is shown as collecting together and passing to the liver. Two arteries are given off to the kidneys and the aorta finally divides into two great trunks—each of the latter divides into branches, the inner supplying the organs lying in the pelvis and the other continued down the thigh as the *femoral artery*, and supplying branches to all parts of the leg.

In the various parts and organs of the body, the smaller arteries break up into capillaries and changes mentioned before take place in the character of the blood. Nutrient substances and oxygen pass out through the thin capillary walls to the tissues, and waste matters and carbon dioxide enter the blood stream, the blood thus changing from a scarlet to a dark colour, that is from pure arterial to impure venous blood. The capillaries unite to form small veins and the small veins open into larger ones, which utltimately

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Fig. 54.—*General view of the Circulation of blood.*
See coloured plate opposite.

Chambers of the heart and blood-vessels carrying pure blood are represented red, those carrying impure blood as blue. Tr., trachea; L.A., L.V., left auricle and left ventricle; R.A., R.V., right autricle and right ventricle; *a.a.*, arch of aorta; *in. a.*, artery dividing into right subclavian and right carotid; *l.c.a.*, left carotid artery; *l.s.a.*, left subclavian artery; *r.a.*, radial artery; *u.a.*, ulnar artery; *d.a.*, aorta;; *st.*, blood vessels of the stomach; *i.b.*, intestinal vessels; *Liv.*, blood-vessels of the liver; *f.a.*, femoral artery; j.*v.*, jugular vein; *r.s.v.*, right subclavian vein; *s.v.c.*, superior vena cava; *f.v.*, femoral vein; *h.v.*, veins from the liver; *i.v.c.*, inferior vena cava; *p.a.*, pulmonary artery; *p.v.*, pulmonary vein.

return the impure blood from all parts of the body to the right auricle. Thus the right and left *jugular veins* from the head and neck, and the right and left *subclavian veins* from the arms, all unite as shown in the diagram (Fig. 54) to form the *superior vena cava*, which opens into the right auricle. The veins from the legs unite to form the *inferior vena cava*, which runs up through the abdomen, receiving the veins from the kidneys and veins from the liver. The veins from the stomach, intestine, spleen and pancreas unite to form the *portal vein* which enters the liver and breaks up into capillaries. Thus the liver receives arterial blood by an artery and blood laden with products of digestion by the portal vein. Both these streams mingle, and blood is returned from the liver by the veins which open into the *inferior vena cava*. The latter passes up through the diaphragm and opens into the right auricle. Thus impure blood from all parts of the body is brought back to the right auricle. From the right auricle the blood goes into the right ventricle and by the contraction of the latter, is sent through the *pulmonary artery*, which divides into two, one going to each lung. In the capillaries of the lungs, the impure blood loses carbon dioxide and water vapour, and obtains a fresh supply of oxygen. This oxygenated blood is returned by two *pulmonary veins* from each lung to the left auricle, from where it goes into the left ventricle, thus completing the round on which it started. It should be particularly noticed that unlike other arteries the pulmonary arteries carry impure blood (hence represented blue in the diagram) and unlike other veins, the pulmonary veins return pure blood to the heart (hence represented red). The muscular walls of the heart do not use any of the blood contained in the chambers of the heart, but get their supply from two arteries (Fig. 48) which arise from the aorta just beyond the semilunar valves. These arteries called the *coronary arteries*, divide into capillaries in the substance of the heart and the capillaries unite to form a vein which opens directly into the right auricle.

As age advances, walls of arteries get thickened by deposition of calcium, and the lumen gets narrow. The arteries also contract temporarily from increased secretion of adrenalin, by fright, emotion, etc. when less blood goes to the heart. This causes pain in the heart region known as *angina*. Angina is also caused in old people by rapid climbing of stairs, walking uphill or strenuous exercise after meals.

The blood has a tendency to clot in contracted coronary arteries known as *Coronary Thrombosis* and causes "heart attack". Angina and coronary thrombosis are more common in persons with high blood pressure, the causes of which are given on pp. 91-92.

Proofs of Circulation.—William Harvey was the first to prove in the seventeenth century that the blood circulates in the body. The proofs now known may be briefly stated as follows:

(1) The spurting of blood from the arteries corresponds to the beats of the heart.

(2) The valves in the heart, the aorta, the pulmonary artery, and the valves in the veins are so arranged as to allow the passage of blood in one direction only.

(3) Poisons injected into a single blood-vessel (e.g. when a snake bites a person) soon produce an effect on the whole body.

(4) If an artery is tied in a living body, it swells up on the side of the heart and becomes empty on the other side. If an artery be cut, the bleeding may be stopped by applying pressure on the part above the wound, i.e. on the side nearer the heart.

(5) If a vein be tied it swells up on the side away from the heart. So when a vein is cut, the bleeding is stopped by pressing on the portion below the wound.

(6) The blood may actually be seen moving by looking at the web of a frog's foot under the microscope. The blood, with the corpuscles contained in it, will be seen running in one direction through a small artery, into a network of capillaries and in the opposite direction into a small vein.

Questions for Examinations

1. Sketch and describe the structure of the human heart and explain its working. How is the blood in the ventricle prevented from going back into the auricles?
2. Describe the different kinds of valves in the heart.
3. What do you understand by pulse? What is the normal number of pulse beats in a person ? How does the frequency of pulse beats vary with the age, sex and activity of a person?
4. Explain the terms: artery, vein and capillary.
5. Prove that blood circulates in the body. What do you understand by *automaticity* of the heart? How is the frequency and force of heart beat regulated?
6. Explain the term Blood Pressure. What are the causes of High and Low Blood Pressure? What precautions should be taken to prevent angina and coronary thrombosis?

CHAPTER XIII

BLOOD-VESSELS : LYMPHATICS

The Structure of Blood-vessels.—The walls of the arteries are thick, strong and elastic, while those of veins are thinner and weaker. On account of this want of elastic tissue the veins collapse when cut while arteries remain open.

Most veins are provided with pocket-shaped valves in their interior which prevent the backward flow of blood. Thus they only allow the passage of blood towards the heart. The presence of these valves can be easily demonstrated by pressing the arm firmly towards the hand, when little swellings appear in the course of the veins at the site of the valves.

The capillaries are generally arranged in the form of a net-work. Their walls are very thin and easily allow the passage of fluid or diffusion of gases, and therefore, the changes that the blood undergoes during the circulation chiefly occur while passing through these vessles.

The Nervous Control of Blood-vessels.—It often happens that a particular part of the body needs more blood than another. Thus when the food is being digested in the stomach, more blood is needed by the stomach than when the latter is at rest. It may be taken as a general rule that more blood goes to the parts when they are active than at rest. This is achieved by the blood-vessels going to the part becoming wider. The smaller arteries are supplied by nerves called *vaso-motor nerves* which have the power of making the blood-vessels wider or narrower.

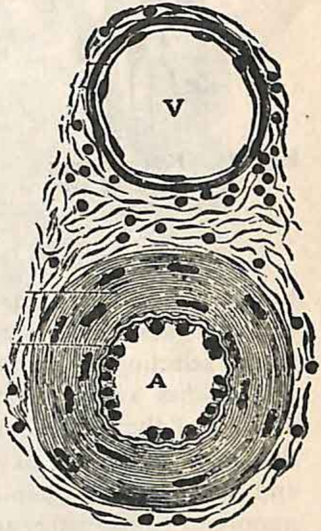

Fig. 55.—*Section of small artery and accompanying vein (magnified).* A. artery; V. vein.

The Lymphatic System.—The lymphatic system consists of vessels and glands, the thoracic duct, and numerous large or small collections of lymphoid tissue found in various organs and tissues and known as lymphoid nodes, and through which passes a watery fluid called the *lymph*. Lymph is the colourless liquid which comes through the walls of the capillaries as the blood passes through them, and consists of water, proteins, carbohydrates and the salts of the blood dissolved in it. It also contains some white corpuscles that have passed out of the blood capillaries, but no red cells. It comes in direct contact with the cells of the tissues and thus serves to bring food to them, the tissues selecting the particular substances they require. It also washes away the waste product resulting from the activity of the tissues. In addition to the food material the lymph carries the oxygen from the blood to the tissues and removes the carbon dioxide produced in them. It is important to remember that the blood in no way comes in direct contact with the cells, but only through the lymph. The lymph is in reality the life-giving fluid for the tissues.

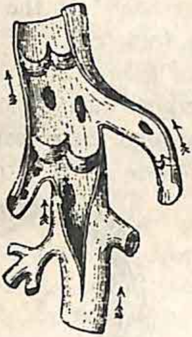

Fig. 56.—*Vein cut open to show pairs of semi-lunar valves.*

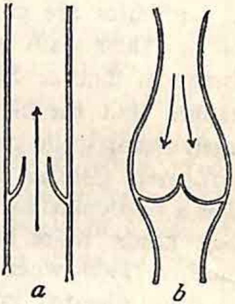

Fig. 57.—*Diagrammatic section of veins to show action of valves.*
a. valves open;
b. valves closed.

After nourishing the tissues and removing the waste products the greater portion of the lymph flows back into the blood capillaries, but a small amount which is not thus absorbed flows into minute spaces which are the beginnings of *lymphatic capillaries*.

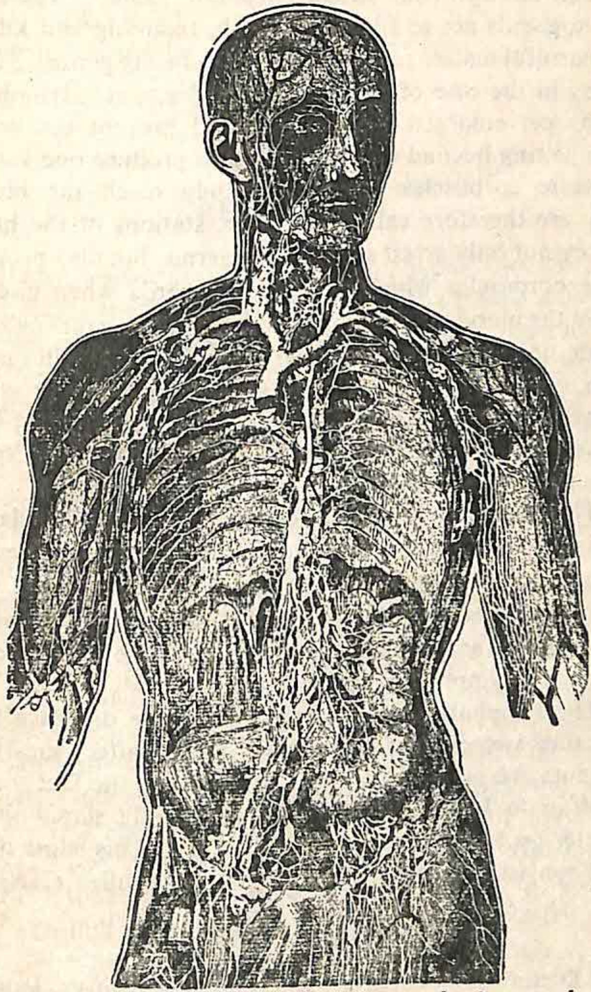

Fig. 58.—*Diagram of Lymphatic System, showing vessels and glands (white).*

The lymphatic capillaries unite with similar vessels coming from neighbouring groups of cells and ultimately form larger *lymphatic vessels* which on their course pass through enlargements called *lymphatic glands*. The lymphatic glands act as filters of lymph, retaining and killing any harmful matter such as disease-producing germs. That is why in the case of dirty wounds, ulcers, etc., lymphatic glands get enlarged and swollen and prevent the germs from getting beyond them. They also produce one variety of white corpuscles which ultimately reach the blood. They are therefore called the police stations of the body, as they not only arrest and destroy germs, but also produce white corpuscles which will act as guards when circulating in the blood. The lymphatics after passing through the glands unite with similar other lymphatics and ultimately form two large lymph channels, the *thoracic duct* which opens into the left subclavian vein and the *right lymphatic duct* which opens into the venous system at a corresponding place on the right side.

The lymphatic channels on the whole are similar in structure to the veins, but have thin walls which readily collapse when empty, and so are difficult to find. They are provided all through with valves, and the flow of lymph is aided by the muscular movements of the part through which the lymphatics are running.

The lymphatic vessels coming from the digestive tract are called *lacteals* (Lat. *lactis*, milk) because after a meal their contents are milky in colour. It is due to the fact that in addition to lymph they absorb, as already stated in the chapter on Digestion, the emulsified fat. This white milky fluid consisting mostly of emulsified fat is called *Chyle*.

Questions for Examinations

1. Distinguish between arteries and veins. How is the flow of blood regulated in the veins?

2. What are vaso-motor nerves, and what is their function?
3. What is lymph? What are lymphatic glands and what is their use?
4. What is chyle?
5. Briefly describe the lymphatic system.

CHAPTER XIV

RESPIRATION

Need for Respiration.—In the first chapter we have already learnt that every action in the body means a chemical change in some cells. When a muscle contracts, a gland secretes or the brain thinks, some chemical change is taking place in the cells of the tissue concerned. We have also seen that the chemical change is a process of oxidation, the oxygen carried by the blood to all parts of the body uniting with the compound substances and breaking them down. As the result of these breaking down activities a number of substances are produced which are of no use in the body and must be got rid of. As carbon is an element present in all tissues, one of the most abundant of waste products in the body is carbon dioxide. In any part of the body, while the blood is passing through the capillaries, oxygen is given up and passes out through the thin walls of the capillaries, and carbon dioxide passes in and is added to the blood, thus rendering the latter venous and changing the bright scarlet colour to a dark purple. The venous blood from all parts of the body is returned to the right auricle and passing down into the right ventricle is sent out to the lungs, in the capillaries of which is effected an opposite exchange of gases, carbon dioxide and water vapour being thrown out and a fresh supply of oxygen taken in. For this purpose fresh air enters the lungs and fouled air is expelled with every breath. *Respiration* or breathing is thus the process by which a fresh supply of oxygen is obtained and carbon dioxide removed.

Differences between Pure and Respired Air.—The air is a mixture of several gases. Pure air contains nearly 79 per cent of nitrogen and about 21 per cent of oxygen, together with a mere trace of carbon dioxide and a variable quantity of water vapour. As the blood passing through the capillaries of the lungs throws off certain waste matters and takes in oxygen there are many differences between the air we breathe in and the air we breathe out. The expired air contains 16 to 17 per cent of oxygen and 4 to 5 per cent of carbon dioxide. The percentage composition by volume of inspired air and expired air is given in the following table:—

	Inspired air	Expired air
Nitrogen ...	79.00	79.00
Oxygen ...	20.96	16.50
Carbon dioxide ...	.04	4.50
Water vapour ...	Variable amounts	Saturated

It will thus be seen that the changes consist in a loss of nearly five volumes of oxygen, an increase of about an equal volume of carbon dioxide, an increase of water vapour. The expired air is usually warmer than the inspired air, as it has nearly the same temperature as that of the body. Expired air also contains minute quantities of organic matter thrown out by the body.

The presence of carbon dioxide in the expired air may be shown by breathing into clear lime-water. Take a small quantity of lime-water in a small tumbler or cup and breathe into it through a glass tube, the end of which is dipping under lime-water. Make each expiration as long as you can. The water gradually becomes milky. This is due to the union of carbon dioxide with the lime to form calcium carbonate or chalk. The presence of water vapour may be shown by breathing on a slate or a cold glass plate, when the latter is seen to be covered with moisture. That the expired air is warm is easily borne out by our experience on a cold day of blowing our hands to warm them.

Organs of Respiration.—In order to reach the lungs the air passes through the nose or mouth into the *pharynx* (throat) and thence into the *larynx* (voice box) which is situated at the top of the wind-pipe or trachea. In passing through the nose, the air becomes warmed, as well as freed from particles of dust by hair situated inside the nostrils. It is important therefore to breathe through the nose and not through the mouth. The pharynx communicates witl the larynx and trachea and also with the other tube, the food-pipe which leads to the stomach. The opening into the larynx (*glottis*) is guarded by a cartilaginous lid called *epiglottis*. Ordinarily the epiglottis stands erect permitting the air to pass freely into the larynx but during swallowing it is pulled upwards and backwards thus serving to close the entrance and preventing food and drink from passing into the larynx (Fig. 38).

The *trachea* or wind-pipe is about five inches in length and is made stiff by incomplete rings of cartilage contained in its walls. But for these rings, the trachea would collapse with the slightest pressure and cause choking. The tube is completed behind by a membrane which is capable of yielding when the neighbouring tube, the gullet is stretched by some food passing through it. The trachea runs down the neck, in front of the gullet and passes into the thorax. Here it divides into two branches known as the right and the left bronchi. Each bronchus enters a lung, and within it divides again and again into smaller and smaller bronchial tubes. The structure of the bronchi and bronchial tubes is similar to that of the trachea, but the smallest bronchial tubes have no cartilage in their walls. The trachea and the bronchial tubes are lined with a mucous membrane which is kept moist by a secretion of some of its cells. The inner layer of cells composing this membrane is provided with fine hair-like processes called *cilia.* The cilia are constantly working, driving any dust that may reach the air passages, up into the throat, from where it may be coughed out.

The two *lungs* are greyish-looking, spongy and elastic organs, which fill during life the cavity of the thorax on each side of the space occupied by the heart. In each lung the bronchial tubes divide and subdivide to such an extent that the smallest of them can be seen only with the aid of a microscope. Every one of these smallest bronchial tubes ends in a bunch of swollen sacs. Each of these sacs has

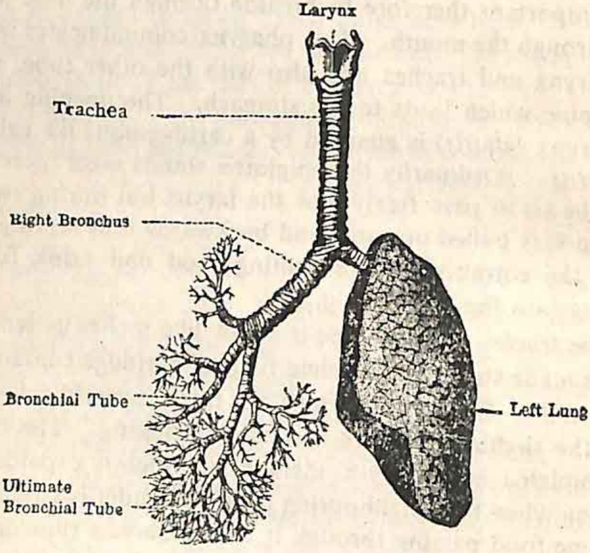

Fig. 59.—*Larynx, Tracea and the Lungs.*
(From Miller's 'Physiology'. W. Collins, Sons & Co. Ltd., By permission).
One lung has been dissected to show the air tubes.

numerous small pouches known as air-sacs. The lung thus consists of millions of tiny air-sacs packed together, each air-sac communicating through the bronchial tubes with the outside air. These sacs look like bunches of grapes, each air-sac corresponding to one grape in the bunch. By this arrangement of innumerable minute bronchial tubes opening into a still larger number of air-sacs, the surface which comes in contact with the air is vast, being estimated at no less than about fifty-five times as great as the entire outer surface of the body. The walls of these air-sacs are very thin, being composed of a fine layer of flattened cells. It is between these thin walls that blood-capillaries derived from the repeated branching of the pulmonary artery are spread out. The venous blood circulating in these capillaries is thus separated from the fresh air in the air-sacs by the exceedingly thin wall of the capillary and equally thin wall of the air-sac. When gases are separated by such thin partitions they can readily mix with one another or diffuse. In this case owing to the powerful attraction of hæmoglobin of the red blood corpuscles for oxygen some

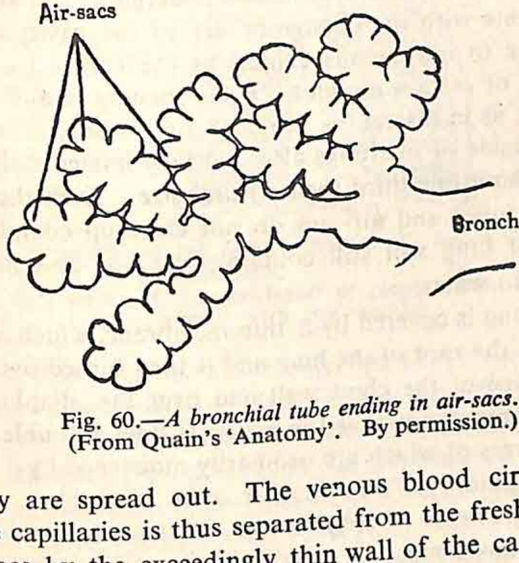

Fig. 60.—*A bronchial tube ending in air-sacs.* (From Quain's 'Anatomy'. By permission.)

of that gas passes into the capillaries and some carbon dioxide passes from the blood into the air-sacs.

The blood in the capillaries thus becomes oxygenated and changed from dark venous to bright arterial. These capillaries unite to form small veins, which uniting with other similar veins form the pulmonary veins that take the oxygenated blood to the left auricle of the heart.

The greater part of the lung is formed of the air-sacs filled with air. The thorax being an air-tight cavity keeps off the pressure of the outside air, but the same atmospheric pressure is exerted through the air in the bronchial tubes and air-sacs and stretches the lungs so as to completely fill the space in the thorax. In life the lungs are naturally in an expanded condition undergoing a change in their volume with the change in size of the cavity of the thorax due to movements caused by the contraction and relaxation of certain muscles. If an opening is made into the thorax as in dissection, atmospheric pressure is exerted on the outside of the lungs also and they immediately collapse to about one-third their natural size. Even then the bronchial tubes and air-sacs do not close up completely. A piece of lung will still contain some air, and float if thrown into water.

Each lung is covered by a thin membrane, which covers it as far as the root of the lung and is then turned over the inner surface of the chest wall and over the diaphragm. This membrane known as the *pleura* is thus a double bag, the two layers of which are ordinarily moistened by a little fluid and glide over one another quite smoothly.

The Movements of Respiration.—It is obvious that the air in the lungs must be constantly renewed or it would lose all oxygen and become loaded with carbon dioxide. This is done by regular movements of the diaphragm and the chest wall.

We have learnt above that the cavity of the thorax is an air-tight chamber, which opens to the outside only through the trachea, and that the pressure of the air in the passages keeps the lungs in a distended condition. When the cavity is enlarged, the pressure of the air would cause the lungs to expand to a greater extent to fill the extra space, and on the contraction of the cavity the lungs would also contract to force out the extra quantity of air taken in. These two movements are performed regularly about seventeen times per minute.

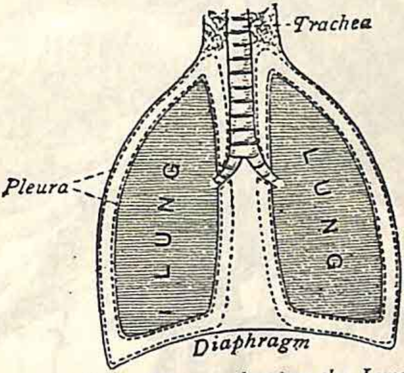

Fig. 61.—*Diagram of the Thorax showing the Lungs, Pleura and Diaphragm.*
Dotted lines represent the two layers of pleura, which are really in contact with one another.

The *diaphragm* is a muscular partition between the thorax and the abdomen. It is like a dome with its convexity towards the thorax and concavity towards the abdomen.

When the muscular fibres of the diaphragm contract, it becomes flatter and less dome-shaped. The cavity of the thorax is enlarged from top to bottom. This descent of the diaphragm presses upon the organs in the abdomen and causes the abdomen to swell out. When the diaphragm relaxes and consequently rises up again, the cavity of the throax is diminished. These two movements of the diaphragm are the principal factors in ordinary quiet breathing.

The cavity of the thorax is enlarged in another way also. The walls of the thorax are formed by the ribs, which articulate with the vertebræ behind and the sternum in front. The space between the ribs are occupied by strong muscles called the *intercostal muscles*. There are two layers of these muscles, the outer being called the external intercostal muscles and the inner the internal intercostal muscles. When the external intercostal muscles contract, they pull up the ribs. As the slanting ribs are pulled up, they push the sternum forward and so the cavity of the thorax is

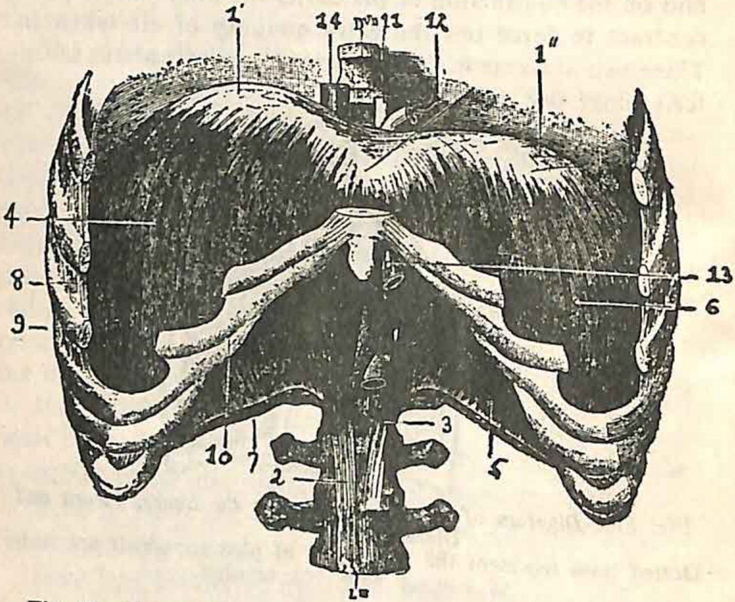

Fig. 62.—*View of Diaphragm, with its convex upper surface in front.* (From Testut's 'Anatomy'. By permission.)

1,1′ and 1″ the central tendon; 2 and 3, pillars of the diaphragm
inserted into the lumber vertebræ; 4 and 6, muscular sheet passing
to ribs; 5, hinder lower surface; 9, section of a rib 10, costal
cartilage; 11, 12, aorta; gullet; 14, lower vena cava; D. VII, seventh
dorsal vertebra:; L III, third lumber vertebra.

enlarged from front to back. The raising of the ribs is accompanied by a slight opening-out of the angle which the bone makes with its cartilage, and thus there is an increase in the width of the cavity from side to side also. The enlargement by means of the side walls takes place at the same time as the flattening of the diaphragm, so the cavity of the thorax is enlarged in three diameters, viz.

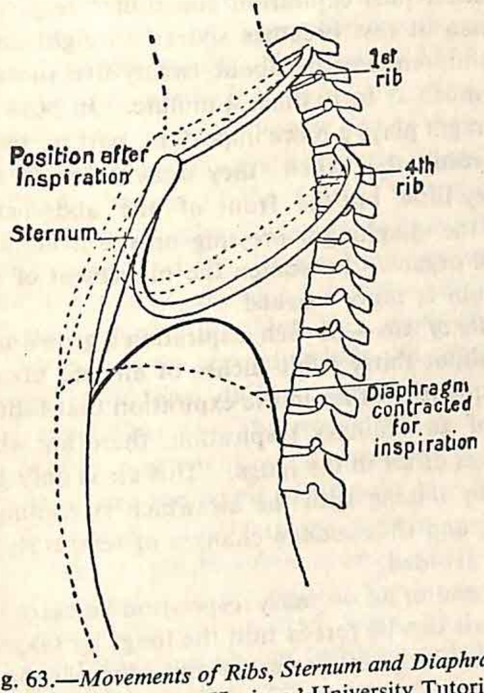
1st rib
4th rib
Position after Inspiration
Sternum
Diaphragm contracted for inspiration

Fig. 63.—*Movements of Ribs, Sternum and Diaphragm.* (From Lyster's 'First State Hygiene,' University Tutorial Press. By permission.)

from side to side, from front to back and from top to bottom. As a result of this increase in the volume of the thorax air rushes down the air passages to distend the lungs, and inspiration is the result. Immediately after the inspiration, muscles causing the movements of inspiration cease to contract. The diaphragm relaxes and becomes dome-shaped and the ribs and sternum fall back to their former position. By these combined movements, the chest cavity becomes smaller and the air is forced out of the lungs, the elasticity of the latter also aiding in the process. This turning out of the air constitutes an *expiration*, which as you see is largely a passive act.

Inspiration plus expiration constitutes respiration. A healthy man at rest breathes sixteen to eighteen times a minute; children breathe about twenty-five times and an infant as much as forty times a minute. In boys and men the diaphragm plays a more important part in respiration, with the result that when they draw a breath the chest moves very little but the front of the abdomen bulges owing to the diaphragm pressing on the liver and other abdominal organs. In women the movement of the ribs and sternum is more marked.

Quantity of Air.—At each inspiration a grown-up person takes in about thirty cubic inches of air and breathes out an equal quantity of air in the expiration that follows. At the end of an ordinary respiration, there are above 200 cubic inches of air in the lungs. This air is only gradually renewed by mixing with the air which is coming in and going out, and thus sudden changes of temperature in the lungs are avoided.

At the end of an ordinary respiration an extra 100 cubic inches of air can be forced into the lungs by taking a deep breath. Similarly at the end of an ordinary expiration an extra 100 cubic inches can be driven out by forced expiration. The maximum volume of air that can be exchanged in a single forced respiration represents the *vital capacity* of the lungs. The vital capacity is ordinarily about 4100 to 5000 cc but is dependent on the physical condition of the body, especially of the lungs.

Thus we find that in ordinary breathing we do not expand our lungs to their full extent, nor do we empty them completely. The more completely the air in the lungs is changed the better will be the resulting ventilation of the lungs. It is good, therefore, to form the habit of deep breathing for a few minutes every morning and evening.

Effect of Exercise on Respiration, The Chemical Control.—Breathing becomes more rapid during exertion of any kind. When running, one pants for breath. This is due to the fact that the muscles are working hard, using up more oxygen and producing more carbon dioxide. The increased amount of carbon dioxide and to some extent the diminution of oxygen circulating in the blood so affects the respiratory centres in the brain, that messages are sent out to various muscles concerned to cause more rapid movements or respiration. These rapid movements not only serve to oxygenate the blood, but also help to increase the pulmonary circulation. Not only more air but more blood is drawn into the expanding lungs during inspiration, and driven out of them during expiration.

The Nervous Control.—The respiration movements are going on without any attention on our part. According to one view these are the result of nervous impulses passing through the vagus or tenth cranial nerve to the diaphragm and the intercostal muscles from a small centre—the respiratory centre situated in the part of the brain called the medulla. According to another view, the respiratory centre is two-fold, consisting of inspiratory and expiratory centres acting reciprocally. These respiratory centres are scattered in the brain stem and are constantly giving off rhythmical stimuli to the respiratory muscles in virtue of their inherent rhythm, causing inspiration and expiration. Whatever view is correct, the respiratory centre or centres receive impulses through nerves distributed in the substance of the lungs or through ingoing (efferent) sensory nerves generally, and normally it is in response to these afferent impulses that outgoing (efferent) impulses are sent to the respiratory muscles. The rhythm of respiratory centres is under the chemical control as mentioned above. Some authorities, however, are of opinion that these centres are also under the control of higher brain centres.

Questions for Examinations

1. What do you understand by respiration, and what is its use?
2. Explain the difference between inspired air and expired air.
3. What are the organs of respiration?
4. Explain the structure of the lungs. What changes are produced in them during the progress of respiration?
5. What is the effect of exercise on respiration and how is it effected?
6. Briefly describe the nervous control of respiration.

CHAPTER XV

THE KIDNEYS AND THE EXCRETION OF URINE

Metabolism.—We have learnt that during the various activities constituting life, some cells of the tissues die and break up (katabolism), while new cells are formed and replace the old ones (anabolism). The vital processes of katabolism and anabolism are going on side by side and the sum total of the activities of the body is described as metabolism.

During the various katabolic activities, certain waste products, especially oxidation products of carbon (viz.

CO_2), hydrogen (viz. H_2O), and a nitrogen-containing compound known as *Urea* are formed, which are finally washed by the lymph into the venous circulation. These must be continuously removed from the system, otherwise they would cause poisoning and death. They are normally removed from the body by the lungs, the kidneys and the skin. To a very small extent the liver also helps in removing waste products, in the form of bile. The organs that remove the waste products from the body are known as Excretory Organs. We have in a previous chapter described the lungs and the liver and the intestines which act as excretory organs to some extent. We shall here consider the work of the kidneys and in the next chapter that of the skin.

The Kidneys.—The kidneys are two in number, situated one on each side of the vertebral column and in front of the last ribs. They are thus situated fairly high up in the body. They are dark-brown in colour and are embedded in a mass of fat. On the upper end of each kidney rests like a cap, a small ductless gland called *supra-renal body*, the function of which has been referred to in a previous chapter. The kidneys have a well-known bean-shaped appearance, the outer edge being convex, and the inner concave, the latter being marked by a depression called the *hilum* or *hilus*. Here the blood-vessels of the kidney, i.e. an artery and a vein, enter and leave the organ and the *ureter* or the duct of the kidney comes out. The ureters pass downwards to open into the bladder. The *bladder* is a muscular bag lying in the pelvis, in which the urine is collected. The urine is constantly being poured into the bladder by the ureters and when it gets filled, the bag contracts and the urine is passed through the *urethra*, a small tube opening to the outside of the body. The urethra is kept closed by a ring of muscular fibres, which relaxes only when urine is to be passed out.

The urine is composed of two nitrogen-containing organic compounds, *urea* and *uric acid*, and certain non-nitrogenous salts, chiefly sodium chloride, and phosphates, sulphates and oxalates of calcium, potassium and sodium, and dissolved in a large quantity of water.

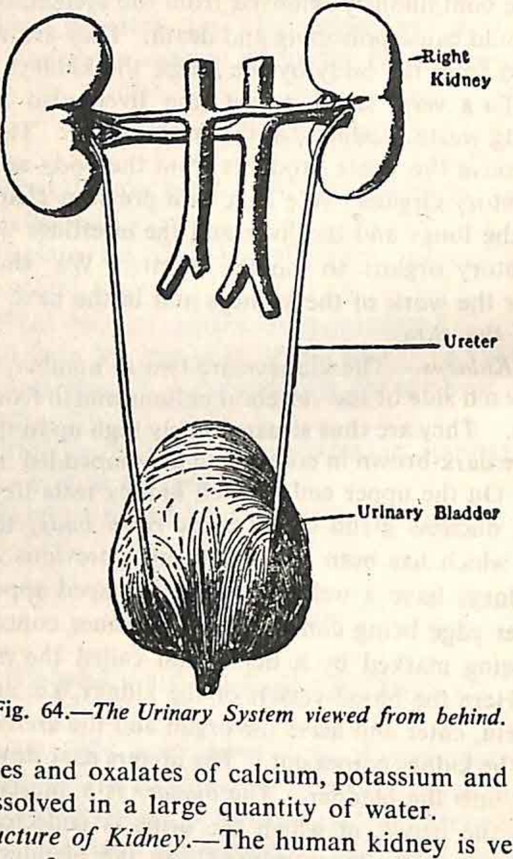

Fig. 64.—*The Urinary System viewed from behind.*

Structure of Kidney.—The human kidney is very much like that of a goat or sheep, and specimens of the latter may be obtained from a butcher for purposes of study. If a longitudinal section of the kidney be made by cutting with a long knife from the outer convex surface to the hilus, it will be seen that the ureter widens out into a cavity with a number of short wide branches. The large cavity is called the *pelvis* of the ureter and its branches *calyces*. In other words the various calyces unite to form the pelvis.

The cut surface of a solid portion of the kidney consists of an outer dark coloured and granular *cortical portion* or the *cortex* and an inner paler portion called the *medullary substance* or the *medulla* of the kidney. The medulla is streaked in appearance and is made up of numerous fine tubules arranged in conical portions called *pyramids*. The base of each pyramid lies towards the cortex, while its pointed

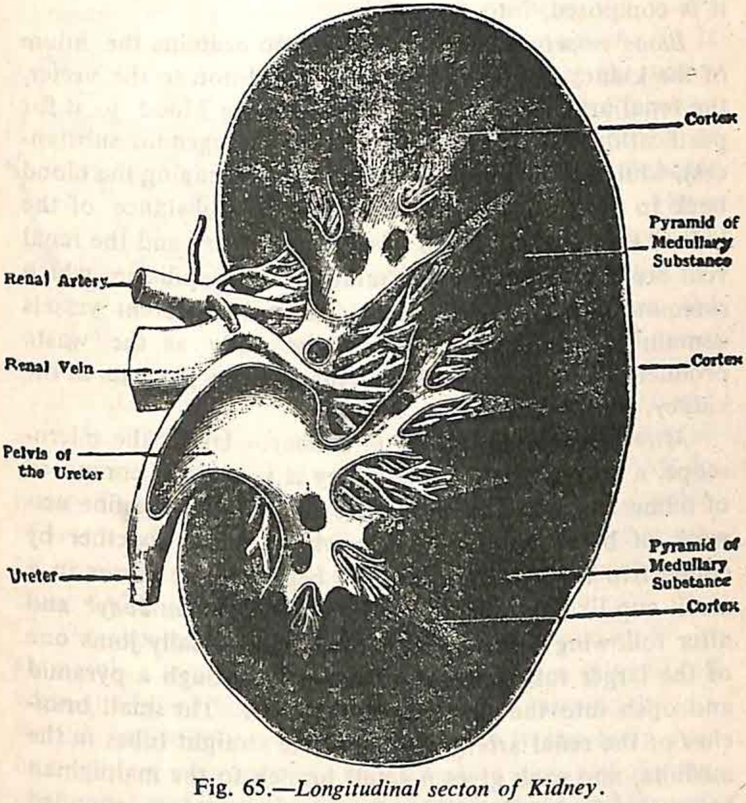

Fig. 65.—*Longitudinal secton of Kidney*.

end projects into one of the cup-like branches of the pelvis. Bands of cortical substance are also seen to run inwards between the pyramids. By squeezing a pyramid some urine may be seen to flow from the tubules of which it is composed, into the pelvis.

Blood-vessels of the Kidney.—If you examine the hilum of the kidney you will find that in addition to the ureter, the renal artery enters the kidney carrying blood to it for purification (i.e. separation of waste nitrogenous substances), while the *renal vein* comes out of it bringing the blood back to the general circulation. In the substance of the kidney the small branches of the renal artery and the renal vein are united together by minute renal capillaries which surround the kidney tubules. The renal efferent vessels contain the purest blood in the body as the waste products have been removed through its passage in the kidney.

Microscopic Structure of the Kidney.—Under the microscope, a thin section of the kidney is seen to be composed of numerous long coiling tubules surrounded by a fine network of blood capillaries, the whole bound together by connective tissue. Every tubule begins in the cortex in a small cup-like expansion called the *Malpighian body** and after following a somewhat coiled course finally joins one of the larger tubes which run straight through a pyramid and open into the funnel-shaped pelvis. The small branches of the renal artery run along the straight tubes in the medulla, and each gives a small branch to the malpighian body which breaks up in its interior into a rounded bunch of blood capillaries called a *glomerulus*. The blood is then collected by a small vein which is of a smaller diameter than the ingoing artery. It again breaks up into small capillaries which surround the urinary tubules and finally unite into veins which running through the medullary portion open into the renal vein.

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* Named after Malpighi, an Italian anatomist of the seventeenth century.

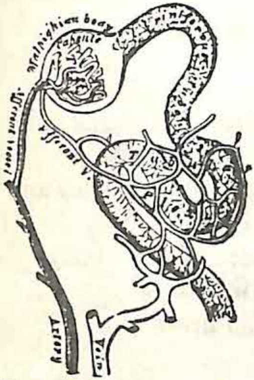

Fig. 66.—*A kidney tubule and its blood-supply (highly magnified).*

Function of the Kidneys:—The function of the kidneys is to purify the blood by removing the waste products of metabolic activities. It acts as a filter removing the nitrogenous compounds called urea and uric acid, along with the excess of chlorides, sulphates and phosphates of sodium and potassium. These organic and inorganic substances are held in solution in a large quantity of water, also separated from the blood, and the fluid is called *urine*. Urine is a pale, yellow liquid with a specific gravity of about 1020, and slightly acid in reaction. About 50 ounces of urine are excreted in twenty-four hours, the amount varying with the quantity of water taken and the amount given off as perspiration. Normally no sugar or albumen is present in the urine and if any is found it is a sign of disease.

The separation of urine from the blood occurs in the glomeruli. Large quantities of plasma are filtered off when the blood is flowing under pressure through the glomeruli, but substances which are useful to the body such as inorganic salts together with a certain quantity of water are reabsorbed into the blood as the urine passes through the tubules. It must be remembered, however, that kidneys only act as filters and that the urea and uric acid are not prepared by the kidneys but by the liver and muscles.

The secretion of the urine by the kidneys is a continuous process and it passes drop by drop into the bladder from which it is passed out at intervals. If by any cause, such as disease of the kidneys, the kidneys do not work and are unable to remove the waste products from the blood, the body gets poisoned and the person dies.

Questions for Examinations

1. Explain the terms katabolism and anabolism.
2. Explain the parts of the urinary system and their working.
3. Sketch and describe the structure of the kidney and its functions.
4. Describe the microscopic structure of the kidney.
5. Name the important excretory organs.
6. Describe the properties of normal urine.

CHAPTER XVI

THE SKIN AND THE EXCRETION OF SWEAT

BODILY HEAT

The Skin.—The skin covers the whole of the body and protects the muscles lying under it. It is also an organ for the *removal of useless materials*, *regulation of the temperature* of the body, and for the *sensation of touch and temperature*, and production of Vitamin D.

The skin consists of two layers, the outer layer or the *epidermis* and the deeper layer or the *dermis*.

The thickness of the epidermis varies in different portions of the body, being about 1/20 of an inch over the soles of the feet and about 1/200 of an inch over the face. The epidermis or the outer layer is hard, formed of many layers of epithelial cells the most superficial of which are scale like and almost horny in nature. They are for the protection of the deeper cells and are continually being worn off and replaced by the deeper cells. The deeper part of the epidermis contains granules of pigment, which gives the skin its special colour, whether dark or brown or fair. In the Europeans the amount of pigment is generally small, and it is greatest in the skin of the negro. The pigment is a gift of nature, better adapting the coloured races to live in tropical climates, and protecting the, body from the strong rays of the sun.

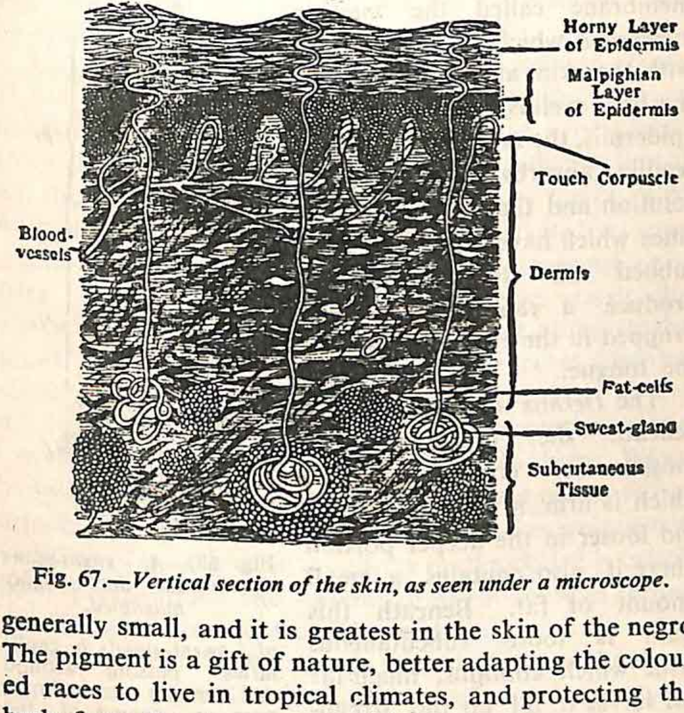

Fig. 67.—*Vertical section of the skin, as seen under a microscope.*

There are no blood-vessels in the epidermis and the cells of its deeper layer are nourished by the lymph which oozes out from the vessels in the dermis. There are only a very few fine nerve fibres passing into them and it is for this reason that we do not feel pain when the epidermis alone is injured.

When seen under a magnifying lens, the surface of the epidermis is seen to be full of small pores, which are openings of the ducts of the sweat-glands which secrete perspiration.

The various cavities of the body are lined with a soft pink membrane called the *mucous membrane* which is continuous with the skin at the margins of the lips, eyelids, etc. Unlike the epidermis, the mucous membrane readily absorbs substances in solution and that is why medicines which have no effect when rubbed on the intact skin, produce a rapid effect when dropped in the eyes or put under the tongue.

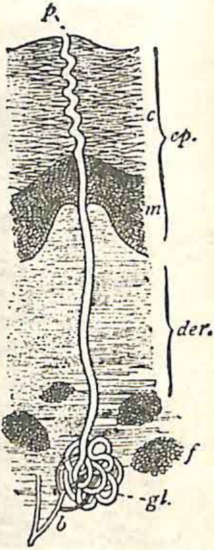

Fig. 68.—*A sweat-gland with its duct highly magnified.*

gl., sweat-gland; *b*, capillaries passing around and among its coils; *p*, pore or opening of the duct; *ep.*, epidermis with *c.*, horny layer, and *m*, Malpighian layer; *der.*, dermis; *f.* fat cells.

The *Dermis* or true skin lies beneath the epidermis and consists of connective tissue which is firm in its upper part and looser in the deeper portion where it also contains a small amount of fat. Beneath this again is loose subcutaneous tissue which contains, much far and serves to fill up the irregularities in the underlying parts and thus give to the body a plump appearance. The looseness of the subcutaneous tissue enables us to pinch up the skin, while the large amount of fat serves not only as a store of energy but also keeps the body warm by preventing loss of heat, as fat is a bad conductor of heat. The dermis is well supplied with nerves, blood-vessels and lymphatics. The upper surface of the dermis shows distinct finger-like projections called papillæ, arranged in a close set parallel rows. Each papilla contains a bunch of blood capillaries and an oval nerve ending called a *touch-corpuscle*. In most sensitive parts of the skin these papillæ are very abundant and the epidermis lying over them is thin.

Skin glands.—The skin contains two kinds of glands (1) the *sebaceous* glands which secrete an oily fluid and are found in connection with the hair and (2) the *sweat-glands* which produce perspiration. We have already mentioned that the pores in the skin are the openings of the ducts of sweat-glands. Each *sweat-gland* is a small coiled-up tube in the subcutaneous tissue surrounded by numerous capillaries. As the blood circulates through these vessels, the cells of the gland secrete sweat and pass it along to the surface through the long spiral duct. The sweat contains water, sodium chloride and urea. It is poured out on the surface of the skin and is carried off by evaporation unless it is very large in amount when it collects in drops. When the sweat evaporates into the air as soon as it comes to the surface, it is called *insensible* perspiration, for we are not conscious of it. But when it collects on the skin it is called *visible* perspiration. The amount of sweat secreted varies with the season, amount of exercise taken, etc.

One of the uses of sweat is to keep the body at the same temperature. Thus during the hot weather or after hard physical exercise when there is a great amount of heat produced in the body, the skin cooled is by the evaporation of an increased amount of perspiration. During the evaporation of any liquid, heat is taken up from the body with which the liquid is in contact, thus lowering its temperature. Thus by the evaporation of sweat the skin is cooled. The increased production of sweat in the hot weather oi after exercise is chiefly due to the expansion of blood capillaries in the skin and the consequent increased flow of blood to the skin.

Nails and Hairs.—These are only outgrowths of epidermis and consist of modified epidermal cells changed into a horny substance. The dermis at the root of the nail is very vascular and cells of the epidermis covering it multiply very rapidly. The cells so formed become compressed and horny and push forward, thus increasing the nail in length.

The hairs are also produced from epidermis. Each hair consists of a shaft and a root and is provided with a small gland called a sebaceous gland which secretes an oily substance to lubricate the hair.

Every hair has got a small involuntary muscle attached to its follicle, which by its contraction makes the hair more erect or as popularly described 'stand on end'.

Cleanliness.—It is clear from what we have described above that if the skin is not properly cleansed, a cake of dirt consisting of cast off epidermal cells, dust, oily subtance and sweat is liable to form over it. In this germs grow and give rise to skin diseases, and it also interferes with the skin doing its proper work, throwing an extra burden on the kidneys. If the kidneys are not able to perform the heavier work thus thrown on them they get diseased. Again, if from any cause evaporation of the sweat is prevented, the temperature of the body is liable to rise. It is therefore necessary to look upon the skin as an important organ of the body and keep it in a clean and healthy condition.

Maintenance of Bodily Heat.—The chief tissues which produce heat are those in which active chemical changes are going on, such as the *muscles*, the *liver*, the *secretory, glands* and the *nerve centres*. These chemical changes are chiefly of the nature of oxidation, producing carbon dioxide and generating heat. It is, therefore, obvious that the more active are the muscles, glands or the brain, the greater is the oxidation and consequent production of heat. As already stated the various foodstuffs differ in the amount of heat which they produce when oxidized in the body. Thus weight for weight, oils and fats produce, twice as much heat as proteins or carbohydrates. That is why in winter or when on active training we eat more fats than in summer or when doing less active work.

Alongside this continuous production of heat there is going on a loss of heat from the body, thus keeping the average surface temperature uniformly, at 98.4°F. The loss of heat is due to the body being warmer than the surrounding air, the heat being lost by radiation, conduction and through evaporation of sweat. In summer, however, when the surrounding air is often warmer than the body, the loss of heat takes place chiefly by evaporation of the large amount of sweat.

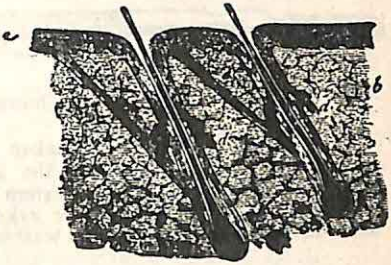

Fig. 69.—*Section of the skin, showing hair-follicles, sebaceous glands, and the muscles of the hairs.*
(From Quain's 'Anatomy'. By permission.)
a, epidermis; *b*, dermis; *c*, muscles of the hair-follicles; *d*, sebaceous glands.

The temperature of the body is kept constant by the regulation of heat production and heat loss. Although the production and loss of heat is to some extent voluntary, i.e. under the control of the individual, as by exercise, use of warm clothes, baths etc., the regulation of the temperature is involuntary and governed by the nervous system. Thus through the nerves going to the blood-vessels, the blood supply of the skin is regulated and the secretory action of the sweat-glands controlled. That is how in cold surroundings, the skin becomes pale preventing further loss of heat, while in a warm atmosphere it gets flushed and moist, thus increasing the loss of heat by radiation, conduction, and evaporation of sweat. We also use clothing to assist us in preventing undue loss of heat from the body. When not well provided with sufficient clothing in winter, we shiver, the muscles being thrown into contractions to produce more heat.

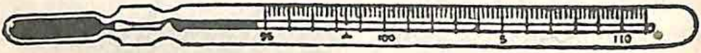

Fig. 70.—*A Clinical Thermometer.*

The temperature is usually taken by putting the bulb of the thermometer under the tongue or in the arm-pit, for 1/2 or 2 minutes and reading the degree to which the stem of mercury rises. Before using, however, the mercury should be jerked to near the lower end of the scale and the thermometer well washed, preferably with a disinfectant.

The mechanism for regulating the blood--supply is governed by a centre in the medulla oblongata of the brain. During heat stroke this centre is paralysed, the regulation of temperature is interfered with, and the temperature rises very high—106°F or over.

The temperature of the body is taken by means of a clinical thermometer which is so graduated as to register temperatures from 95°F to 110°F; the average temperature of the body in a state of health (normal) being about 98.4°F.

The temperature is nearly the same in all parts of the body, the uniformity being brought about by the circulation of the blood. A slight rise may however be brought about by active muscular exercise. The feeling of heat or cold, however, does not depend on the temperature of the body. It is well known that even when the body temperature is high as in fever, there may be a feeling of cold or even shivering. This feeling entirely depends upon the state of circulation through the skin capillaries. When these vessels are full and the circulation active, there is a feeling of warmth, while when they are controlled and empty, we feel cold.

Questions for Examinations

1. What functions are performed by the skin?
2. Describe the structure of the skin as seen under the microscope.
3. Describe the sebaceous glands and the sweat-glands. What secretions come out of them? What are the functions of sweat?
4. Describe the structure of hair.
5. How is the bodily temperature maintained. Describe the part played by the skin and the nervous system in maintaining constant bodily heat.
6. Describe a clinical thermometer.

CHAPTER XVII

THE NERVOUS SYSTEM

The Nervous System is the complex system through which the whole body is worked together and controlled. It regulates the various movements of the body, controls the secretions of various glands, the various sensations are perceived and is the seat of intellect, feelings and will. It is in short the king sitting in his palace, protected by strong walls, but in constant touch with the remotest portions of his kingdom and controlling and regulating the minutest details of everyday life.

The nervous system consists of two distinct parts (i) the cerebro-spinal or sematic nervous system, and (ii) the autonomic or visceral nervous system.

The *Cerebro-spinal nervous system* consists of the brain, the spinal cord and the various nerves arising from them, which connect them with peripheral parts and is hence called the peripheral nervous system. Through this system the body reacts to changes in its external environment, leading to consciouness of the external world. But in addition the brain possesses the inherent power of originating impulses, what is called spontaneous action.

The *autonomic* or *visceral nervous system* consists of two parts, the *sympathetic* and the *para-sympathetic* and their activities are antagonistic to each other. The autonomic system controls the activities of the viscera, the glands and the blood-vessels.

The *sympathetic nervous system* consists of two chains situated one on either side in front of the vertebral column and extending from the skull to the pelvis. On the course of these chains or cords are situated numerous small knots (*ganglia*) or collections of nervous matter from which fibres are given off to various internal organs and blood-vessels, as also branches connecting them with the spinal nerves. It regulates the movements of the internal organs, such as the heart, lungs, stomach, etc., and is closely connected with the central nervous system by means of connecting nerves which proceed from the ganglia at various levels.

The *para-sympathetic nervous system* consists of groups of cells situated at different levels in the mid-brain and the sacral region of the spinal cord. The cranial group is formed by the third, the seventh, the ninth and the tenth cranial nerves, while the sacral group is formed by the second, the third and the fourth sacral nerves. The fibres from the third cranial supply the internal muscles of the eye, from the seventh and ninth supply vasodilators and secretory glands in the nose, mouth and pharynx. The tenth supplies the heart, the bronchial muscles, the stomach, the small intestines and regulates their secretory mechanism.

The fibres from the sacral region supply the vasodilators, the bladder and the rectum.

The sympathetic and the para-sympathetic systems are antagonistic to each other. Thus the pupil is contracted by the para-sympathetic but it is dilated by the sympathetic. Similarly para-sympathetic inhibits the heart, while the sympathetic accelerates it. Some organs are supplied by the sympathetic, such as the uterus and most of the arterioles; while the glands of the stomach and the pancreas are supplied by para-sympathetic only.

Nerve Cells.—The nervous matter forming the central and sympathetic nervous system consists of two kinds described from their appearance as the *grey* and the *white matter*.

Under the microscope the grey matter is seen to consist chiefly of *nerve cells*, and the white matter of *nerve fibres*. A nerve cell is very characteristic, composed as it is of a central mass of protoplasm with its nucleus, and many processes given off from it. Most of these processes branch and interlace with those of neighbouring nerve cells, but one of the branches is distinguished from the rest by not branching except as its termination. This last is very long and covered by a sheath and forms a nerve fibre.

Each nerve cell with its processes is quite independent and is not connected with other cells except through the interlacing branches of its processes. A nerve cell with all its processes is called a *neuron*. It is important to note that connection between one neuron and another is made through the contact of branching processes and not through actual continuity of nerve matter.

The whole matter consists of nerve fibres which are continuations from the nerve-cells in the neighbouring grey matter. The whole of the nervous system is thus a collection of neurons.

Nerves.—A nerve is composed of numerous fine nerve

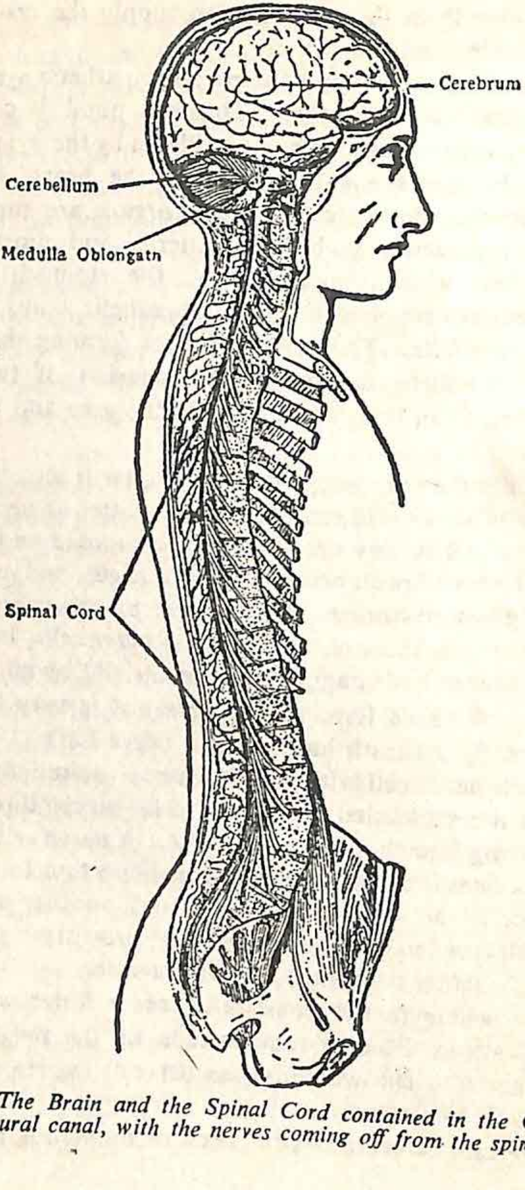

Fig. 71.—*The Brain and the Spinal Cord contained in the Cranium and the neural canal, with the nerves coming off from the spinal cord.*

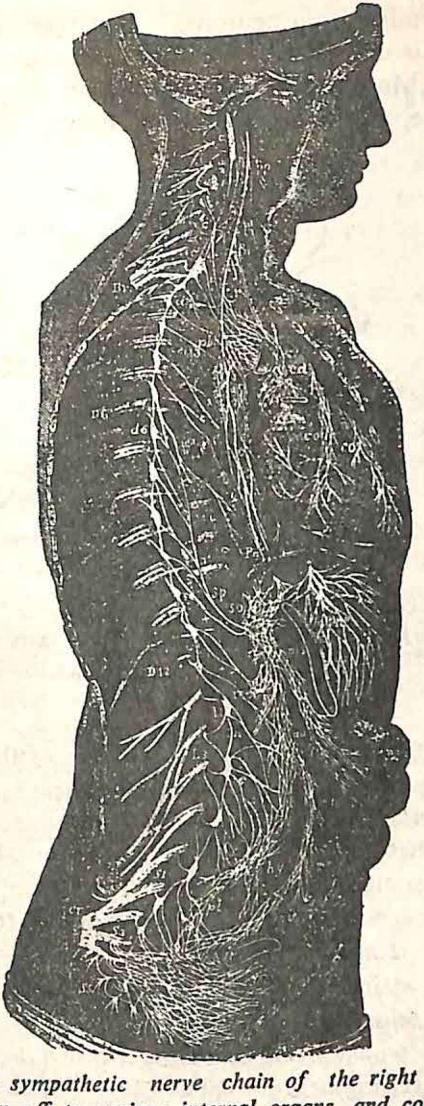

Fig. 72.—*The sympathetic nerve chain of the right side, showing, branches given off to various internal organs, and connections with the spinal nerves.*

fibres coming from neurons, bound together by fine connective tissue. Nerves have the appearance of fine white threads. Most nerve fibres have a thick sheath of fatty substance, called the medullary sheath.

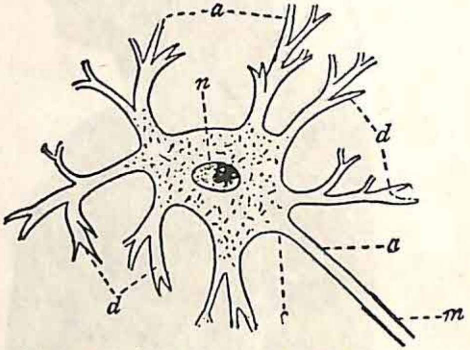

Fig. 73.—*Diagram of a Nerve-cell from the grey matter of the spinal cord, highly magnified.*

c, body of the cell; *n* nucleus; *d*, branching processes: *a* process, which is very much drawn out and forms the axis of a nerve-fibre being covered by a sheath (*m*).

Some nerve fibres particularly those of the sympathetic nervous system, have no medullary sheath.

Afferent and Efferent Nerves;—Nerves are classified into two varieties according to the direction in which they conduct nerve-impulses. Nerves which carry impulses towards a nerve centre are called *afferent* (Lat. *af*, to; and *fero*, I carry) *nerves* and as they usually give rise to some sensation such as feeling of touch, sight, smell etc., are often known as *sensory nerves*.

Nerves which bring impulses from a nerve centre to muscles, glands, etc., are called *efferent* (Lat. *ef*., out; and *fero*, I carry) *nerves*. If a nerve goes to a muscle and by carrying an impulse leads to its contraction, it is called a *motor nerve*. If it leads to secretion in a gland, it is *secretory*, and if it causes changes in the calibre of a blood-vessel, it is known as a *vaso-motor nerve*.

Thus all afferent nerves are not sensory, and all efferent nerves are not motor.

Some nerves are purely sensory while others are purely motor. But the majority of nerves are mixed nerves, that is, they contain both sensory and motor fibres and can carry impulses in both directions.

The rate at which an impulse travels in a nerve is about 100 feet per second, which is very much less than the speed of light or even of an electric current.

The Brain.—The brain is a part of the central nervous system, contained in the cranial portion of the skull. It is enclosed by three membranes, *viz*., the *dura mater*, the *arachnoid* and the *pia mater*.

The dura mater is the outermost, tough, fibrous membrane, next to the skull. Inside it is a delicate membrane called the arachnoid, while within that, closely investing the brain and dipping into its various furrows is the pia mater. This last is very vascular and supplies the surface of the brain with blood-vessels.

The brain consists of the following parts:—

1. The *cerebrum* or the great brain is the large hemispherical mass, forming the greater portion of the brain.

2. Lying underneath the back portion of the cerebrum is the *cerebellum* or the lesser brain.

3. Between the right and the left halves of the cerebellum is a bridge of brain substance, called the *pons Varolii*.

4. Beneath the pons and connecting it with the spinal cord is the elongated *medulla oblongata*.

The Cerebrum.—The cerebrum is divided by a large longitudinal fissure into two equal halves called the *cerebral hemispheres*, but the two hemispheres are connected with one another by a band of nervous tissue, extending below the fissure.

Looked at from the outside the cerebrum is seen to be studded by numerous folds and furrows, called the convolutions and fissures of the brain. The largest of these fissures divide the cerebrum into several distinct lobes. The nervous matter of the brain consists of the grey and the white matter. In the cerebrum the grey lies outside and envelops the white matter. It is therefore called the cortex. It consists of collections of neurons, forming areas which are concerned with particular functions of the brain. The white matter consists simply of fibres of the neurons, coming from or going to the cortex. In the interior of each hemisphere is a distinct cavity known as the *lateral ventricle*.

Functions of the Cerebrum.—The functions of the cerebrum are numerous and complex. Sensations, thought, memory, will, action and emotions are all associated with it. The cerebrum is the seat of the *intellect*, that enables us to think, learn, understand, judge and remember. It enables us to observe things around us through one or other of our five senses (*sensation*). It gives us the power of *will* and voluntary action. Further, this is the part of the brain which produces in us love, hatred, fear, joy, sorrow, etc., that is *emotions*. Different portions of the cerebrum are specialised to perform different functions. Some of them are receiving centres for impulses (sensory centres) while others originate impulses (motor centres). Most of the centres are located in the grey matter of the cortex. The functions of the cerebrum have been determined and the position of most of the centres found out as a result of experiments with animals or observations on persons with diseases of the brain. The following illustrations will give some indication of the nature of such experiments and observations:—

(1) If the cerebrum of a frog's brain is destroyed the frog sits up in the ordinary manner, breathes, swallows, food placed in the mouth—making no attempt to feed itself, turns over and sits up if placed on its back, and swims if placed in water. If left alone it remains in the sitting posture till it dies. It is thus seen that it does nothing of its own accord, but only in response to stimuli received from outside by the spinal cord and the medulla. Such actions are described as *reflex actions.*

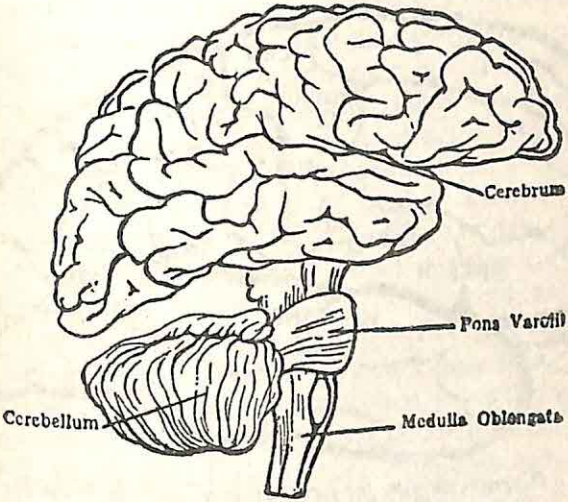

Fig. 74—*Side view of the Human Brain.*
(From Quain's 'Anatomy'. By permission.)
The parts somewhat separated from one another.

(2) If a person receives a blow on the top of his head, causing injury to the brain, he falls down and remains quite senseless without any power of moving. Under careful nursing the brain may repair the injury and the person recover his senses, and his powers of intellect, will and emotions, or if the injury is too severe, the person may pass off in that senseless state.

(3) Some children are born with a cerebrum below the usual size, and are consequently found to be idiots. On the other hand, in the case of men with great intellectual powers, the cerebrum is always very large. Just as an athlete's arms and legs are more muscular, the cerebrum of an educated and thoughtful person is greater and more refined than that of ignorant and careless people. The more diligently you work at your lessons, the more you are developing your cerebrum, and these mental faculties will be of use to you throughout life. Among the various subjects of study, mathematics is the best form of mental athletics.

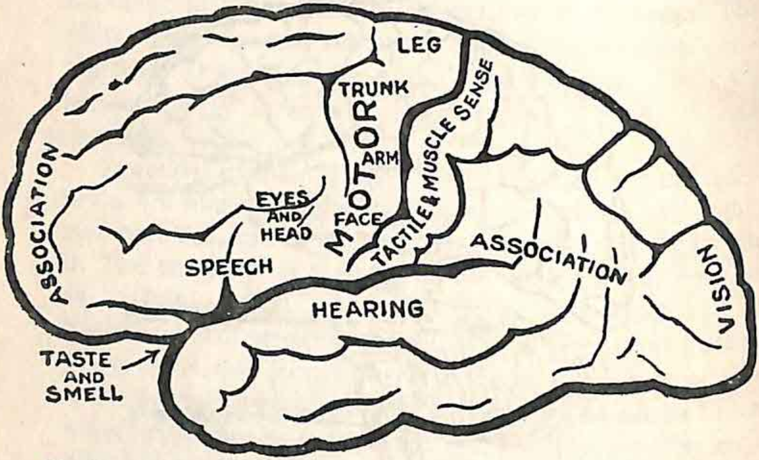

Fig. 75.—*Diagram showing the localization of function in the cortex of left cerebral hemisphere.*
(From Bainbridge and Menzies' 'Essentials of Physiology'. By permission.)

(4) Intoxicating liquors affect this part of man's brain and a drunkard loses his intelligence and will power, and when greatly under their influence, becomes unconscious and falls down as dead drunk. If such a person does not give up this bad habit; he may become a victim of insanity.

The Cerebellum.—Lying underneath the back part of the cerebrum is the *cerebellum* or the lesser brain. It is a bilateral, furrowed structure, consisting of grey matter enclosing a core of white matter. The furrows are very much deeper than in the cerebrum and the pia mater dips into them to some distance.

The functions of the cerebellum are chiefly concerned with the co-ordination of muscular movements and the maintenance of the balance of the body. Through this organ are received afferent messages from the muscles and joints and from the semi-circular canals, and efferent impulses are sent which co-ordinate muscular movements in complicated acts, like walking, running, etc. If the cerebellum is injured the animal becomes giddy and loses his balance. He may still be able to contract a muscle, but cannot run, walk or perform other complicated movements requiring the working together of many muscles.

Pons Varolii.—Pons Varolii (Lt. *pons*. a bridge,—bridge of Varolius) is a bridge-like band of nervous substance passing above the medulla oblongata and connecting the two halves of the cerebellum. Fibres from the cerebrum also pass through it and as they pass they cross one another, fibres from the right cerebral hemisphere going through the left side of the pons to the muscles of the left side of the body, and from the left hemisphere to the right side. Thus an injury of the right cerebral hemisphere causes paralysis or loss of voluntary movement and loss of sensation on the left side of the body and *vice versa*, Just in front of it is a small globular body called the *pituitary body* which has important functions in regard to the development and the growth of the body. These have been described in the chapter on Ductless Glands.

Medulla Oblongata.—Medulla oblongata is a cylindrical mass of nervous tissue, lying between the two cerebellar hemispheres and connecting the brain with the spinal cord. Unlike the other parts of the brain, the grey matter in the medulla lies inside while the white matter is outside.

The Medulla is a very important structure, as all the fibres passing from the spinal cord to the brain pass through it and in it are situated the important centres for respiration, circulation, swallowing, etc. The Medulla is thus the vital portion of the brain and any injury to it causes instantaneous death.

Six pairs of cranial nerves arise from parts of the brain in front of the medulla, and the remaining six from the sides of the medulla.

Cranial Nerves.—Twelve pairs of cranial nerves arise from the under surface of the brain, and they are numbered from before backwards. These pass put of the skull through small holes and are distributed for the most part to the sense organs, or muscles or skin of the head, except the 9th, 10th 11th and 12th, which send branches to other organs and parts of the body as well.

Most of the cranial nerves are purely sensory, a few are purely motor, while some, like all the nerves arising from the spinal cord, are mixed nerves.

The first or the *olfactory* nerve is a sensory nerve which ends in the mucous membrane of the nose, and conveys the sensation of smell.

The second or the *optic* nerve, goes to the eyeball and is the nerve of sight. These nerves are seen to cross each other on the under surface of the brain, just in front of the pituitary body.

The third *oculo-motor*, fourth *trochlear* and the sixth *abducent* are purely motor nerves, and go to the various muscles which move the eyeball in different directions. There are six of these muscles, four recti or straight and two oblique. Of these the superior oblique is supplied by fourth nerve, the external rectus by the sixth and the remaining four muscles by the third nerve, which is thus the chief motor nerve of the eyeball (hence called oculomotor).

The fifth is a mixed nerve, and is known as the *Trigemental*, because it divides into three branches. One of these is a sensory nerve, which spreads itself in the region surrounding the eyeball, nose, mouth, teeth and cheek and ends in the front surface of the tongue. This is the nerve which carries the sensation of pain in neuralgia of the face and teeth, and also the sensation of taste. The two other,

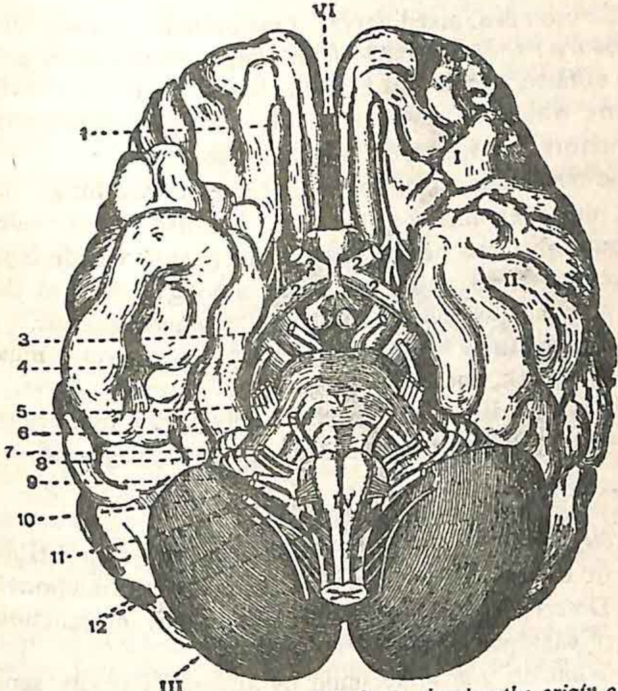

Fig. 76.—*The under surface of the brain showing the origin of twelve pairs of nerves.*

I and II, lobes of the cerebrum; III, cerebellum; IV, medulla oblongata; V, pons varolii; VI, the bridges connecting the two cerebral hemispheres. 1—12, the twelve pairs of cranial nerves arising from different parts of the brain.

branches of the trigemenal are motor and proceed to the muscles which move the jaws during mastication.

The seventh or the *facial* is a purely motor nerve for the face muscles and controls the facial expressions.

The eighth or the *auditory* is the nerve of hearing and goes to the internal ear.

The ninth is a mixed nerve. One branch is sensory and spreads over the back part of the tongue thus serving as a nerve of taste, and the other is motor for the muscles of the pharynx which are engaged in the act of swallowing. It is, therefore, known as the *glossopharyngeal.*

The tenth is a mixed nerve. It goes to the lungs, the heart, the liver and the stomach. Because of its wider distribution, it has been named *vagus* (*vagus*, wandering). On account of its giving branches, among others, to the lungs and the stomach, it is also called *pneumogastric.*

The eleventh is a motor nerve supplying certain muscles of the neck, and is called the *spinal accessory* nerve.

The twelfth is a motor nerve supplying the muscles of the tongue and for that reason named the *hypoglossal.*

Questions for Examinations

1. What are the functions of the nervous system? How do the brain and the nerves carry on their functions?
2. Describe the structure of the brain and the function of each part.
3. What do you understand by afferent, efferent, sensory and motor nerves?
4. Sketch and describe a nerve-cell.
5. What is a cranial nerve? What parts are supplied by the various cranial nerves?
6' Briefly describe the cerebro-spinal and autonomic nervous systems.

CHAPTER XVIII

THE NERVOUS SYSTEM

(*Continued*)

The Spinal Cord.—The spinal cord is a cord of nervous matter, occupying the neural canal running down the vertebral column. It extends from the foraman magnum of the skull to the second vertebra, where it ends in a bunch of nerves. Like the brain it is covered by three membranes, the dura mater, the arachnoid and the pia mater. The spinal cord is divided into lateral halves by two fissures running in front and behind and known as the anterior and posterior fissures. In the centre is a narrow cavity called the central canal of the spinal cord which is continuous with the ventricles of the brain. The various spinal nerves are given off on either side at regular intervals. There are thirty-one pairs of these nerves, and each nerve arises by two roots, an anterior and a posterior root, which unite with each other while still within the neural canal. The nerves come out on both sides through the foramina between successive vertebræ. Like the brain the cord is composed of the grey matter and the white matter, but the grey lies

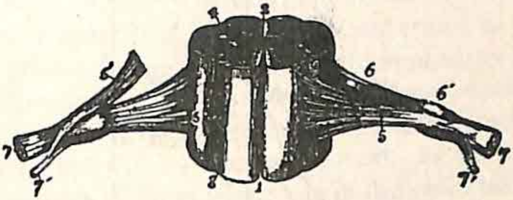

Fig. 77.—*A portion of the spinal cord seen from the front and showing the origin of a pair of spinal nerves.*

The darker H-shaped area in the middle is the grey-matter. 1, anterior fissure; 2, posterior fissure; 3, groove from which the anterior root arises; 4, groove for posterior root; 5, anterior root; 6, posterior root bearing 6′ a ganglion; 7, the united nerve 7′, first branch from the nerve.

inside and the white matter outside completely surrounding the gery.

The grey matter is arranged in the middle of the cord resembling as, seen in sections, the capital H in shape. The limbs of H are curved and lie on either side of the central canal, pointing forwards and backwards. The parts in front of the connecting bridges are called the anterior horns, and those behind the posterior horns. The grey matter of the cord is similar in structure to that of the brain, being composed of neurons and the fibres proceeding from them. The white matter of the cord is composed of modulated nerve fibres. These fibres are coming from or going to the various parts of the brain, bringing nervous

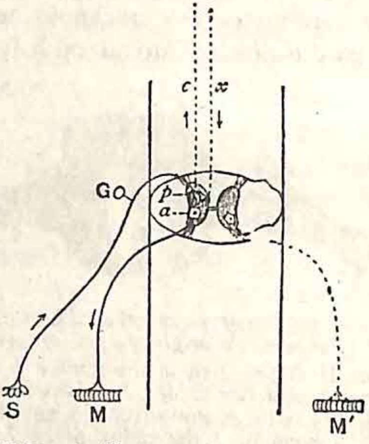

Fig. 78. *Diagram to illustrate the path of nervous impulses in a reflex action of the spinal cord.*

S, sensory surface, from which a nervous impulse passes to the spinal cord by the posterior root of a spinal nerve; G, ganglion on the posterior root; the nerve-fibre breaks up at *p*, and transmits the impulse to a neuron, *a*, in the anterior horn of grey matter; from *a* a motor impulse passes outward along a motor nerve to the muscle M, sometimes an impulse passes to the other side of the cord, and thence to a muscle M′ on the other side of the body In actions other than reflex the impulse to the brain is indicated by the dotted line *c* and the passage of an impulse from that organ by the dotted line *x*.

impulses from the brain to the body, or carrying nervous impulses from the different parts of the body to the brain, the fibres from the right side of the body going to the left side of the brain and *vice versa.*

The anterior nerve root of the spinal nerve arises from the anterior horn and goes to the muscles of the trunk or limbs and is therefore motor. If any motor root is destroyed the animal cannot move the corresponding muscles, but it feels the prick of a needle or any hot substance applied to the corresponding part.

The posterior nerve root of the spinal nerve enters the posterior horn. Its fibres arise in the skin covering different parts of the body and carry sensory impressions: it is therefore the sensory root. If it is cut the animal ceases to feel pain of the prick of a needle in the part supplied by the nerve, but is able to move the muscles supplied by the nerve. Thus every spinal nerve is a mixed motor and sensory nerve.

Functions of the Cord.—The spinal cord, as we have seen above, consists of fibres which run in the white matter and of nerve centres which are found in the grey matter.

The white matter is the conducting portion of the cord and carries messages to and from the brain. The messages from the right side of the body go to the left side of the brain and *vice versa.* Any injury to the cord from disease or accident will prevent the conduction of these impulses, so that the person will not be able to move the limbs or other parts below the seat of injury, nor feel any sensation of touch, pain, or cold from such parts. The parts are said to be paralysed. Life however will continue, so long as the injury to the cord is below the neck, from where the nerves supplying the diaphragm arise. If, however, a portion of the cord in the neck is injured, the diaphragm is paralysed and respiration cannot go on, thus causing instantaneous death.

The neurons in the grey matter of the cord control the contraction of the various muscles supplied by the anterior root of the corresponding spinal nerve. Unlike the neurons in the grey matter of the cortex of the brain, they have no power to initiate movements. If the cord is injured, the muscles supplied from it below the seat of injury cannot be moved at will as its connection with the brain has been cut off. But the animal moves its limbs if it is pinched or irritated, without the brain being concerned in these movements. In this case the nervous impulses conveyed to the cord by the sensory nerve fibres are reflected back by the spinal cord through the motor nerve fibres from the anterior horn, to the muscles of the limbs. Such an action is called *reflex* action. Reflex action is movement that results from the excitation of a sensory nerve, without our being conscious of it. The brain takes no part in these reflex movements. The centres in the spinal cord are called lower centres, because they are under the control of higher centres in the brain and have no power of initiating movements at will. They merely work like a machine.

Three structures are necessary for a reflex action, viz.(1) a sensory nerve arising from a sensory surface, (2) a centre in the cord or lower parts of the brain, and (3) an efferent nerve going to a muscle or gland.

All the various actions that are performed as the result of external stimuli without our being conscious of them are reflex actions. Thus the act of winking when an object is suddenly brought near the eyes, is a reflex act. In this case the afferent nerve is the optic nerve, carrying the sensation to some centre in the brain, and the efferent nerve is the nerve supplying the muscles of the eyelids. Again if the sole of the foot is tickled even while we are asleep, the legs are drawn up. In this case the afferent nerve is the sensory nerve from the skin of the foot. The nerve centre is situated in the lower part of the cord and the efferent nerve is the motor nerve going to the muscle of the leg.

Other examples of reflex action are sneezing when the mucous membrane of the nose is touched, or flow of saliva when any acid substance is put on the tongue. In short most of the actions in our daily life such as walking, cycling etc., become reflex acts after some time. In the beginning when walking and cycling are being learnt they are conscious acts done with the help of will and effort. But later on, they become purely reflex acts.

The Sympathetic Nervous System.—The sympathetic nervous system consists of a chain bearing a large number of ganglia or collections of neurons, lying on either side in front of the vertebral column (Fig.72). From the ganglia communicating branches are given off to the spinal nerves and other fibres run off to various internal organs and blood-vessels. These fibres form, at various places in the body, exceedingly fine networks and supply the heart, lungs, stomach, intestines, urinary bladder and other abdominal organs and control their involuntary movements. As already stated the sympathetic system is connected with the centres of respiration, circulation, etc., situated in the medulla oblongata, through its connection with the vagus nerve.

The sympathetic system exercises an influence over the greater part of the internal machinery of the body, and to some extent controls the functions of digestion, circulation and respiration. Under certain circumstances such as fright, joy, grief, etc., the activity of these organs is influenced through the sympathetic system. A person under the influence of grief feels no appetite and as the result of fear the face becomes quite pale. On the contrary happy news brings colour to the face and the person is said to blush. The emotions first spring up in the mind but their influence is extended to the sympathetic system, the fibres of which, surrounding the walls of the blood-vessels in any part (say the face) exercise a more or less powerful control over them and a smaller quantity of blood is allowed to pass causing paleness; or a greater quantity of blood passes causing the familiar blush.

Questions for Examinations

1. Describe the struture and functions of the spinal cord.
2. What is a reflex action? Give examples of reflex action.
3. What is the function of the sympathetic nervous system? Illustrate its working by examples.

CHAPTER XIX

THE SPECIAL SENSES: TOUCH, TASTE AND SMELL

Sensations.—It is through the nervous system that we derive a knowledge of the external. This knowledge comes to us as sensations. Sensation is a feeling of knowing something produced by the excitation of a sensory nerve. It is due to the stimulation of a specially constructed sense organ, such as the eye or the ear, it is called a special sensation and it is distinctly local in character. Five special senses are well known, viz., senses of *touch*, *taste*, *smell*, *hearing* and *sight*. In addition to these there are special senses of *pain* and *temperature*. But besides these special senses there are other common sensations, produced by the stimulation of widely distributed nerves by the state of the internal organs or blood. The commonest among these are hunger, fatigue, faintness and muscular sense. While there may be produced a marked effect in some particular organ, such as the feeling of hunger in the pit of the stomach, the effect is general and distributed all over the body.

The muscle and joint sense.—It is through this sense that we become acquainted with the condition of contraction of our muscles, of the position of our limbs, and are able to perform delicate movements or estimate the weights of bodies. This sense depends on the degree of compression of muscle spindles in the muscles, and analogous endings in tendons. This sense is different from cutaneous sensations, since it is retained after the skin has been made insensitive by cocaine or disease.

The Special Senses.—As explained above, sensation is the result of the stimulation of a sensory nerve, which carries a message to the brain where the sensation is actually felt. The special structure which receives the stimulus and changes it into a *nervous impulse* is known as a *sense-organ.* Each of the special senses, touch, taste, smell, sight and hearing, has sense-organs situated in particular parts of the body. These are only excited by a particular form of energy, for which alone they are specially adapted. Thus the end-organ of hearing is excited by sound waves, and that of sight by rays of light.

The excitation of a sensory nerve, through whatever cause, always produces the particular sensation to which it is related. Thus the excitation of the nerve of sight, as by pressure on the eyeball, will produce flashes of light, and the irritation of the nerve of hearing from whatever causes will produce the sensation of sound.

Touch.—The sense of touch is widely distributed all over the surface of the skin. It is caused by the stimulation of end-organs of touch or nerve-endings of sensory nerves in the skin and mucous membranes of the mouth and nose, etc. These are called *touch corpuscles* (Fig. 67) and are composed of a mass of cells in which a branch of sensory nerve ends. The sense of touch is most delicate in the tip of the tongue, the tips of fingers, the tip of the nose, and the lower lip. In these places the touch corpuscles are most abundant and are covered only by a thin layer of epidermis.

The sensitiveness of the skin is determined by the ability to distinquish between the points of a pair of compasses placed near together on the surface of the skin. The nearer the two points which are distinctly felt as separate, the more sensitive to touch is that part. Thus while on the top of the tongue the two points can be felt as distinct when the distance between them is only 1/24 of an inch, on the back of the body, it has to be about three inches before two separate points are felt as such. Hence the tip of the tongue is seventy-two times more sensitive than the back of the body.

Temperature and Pain.—Like the sense of touch, the senses of cold, warmth and pain are caused by the stimulation of special corpuscles. These are distributed under the epidermis and are different from the touch corpuscles. The parts most sensitive to temperature are the tip of the tongue, the eyelids, the cheeks, the lips and the hands. It is interesting to note that the skin is not a good judge of the absolute temperature of bodies. Thus if one hand is placed for some time in hot water and the other in cold and then both are placed in tepid water, the same water will feel cold to one and warm to the other. This is due to the fact that the sense of temperature is modified by the state of the blood-vessels of the skin, blood-vessels that are full make us feel warm and blood-vessels that are empty make us feel cold. The pain spots are detected by blindfolding a person and using a sharp needle pressing down firmly but without piercing the skin. It will be noticed that there are points where the sensation of touch or pressure is felt while at other points pain is felt. Similarly hot and cold spots can be marked by filling two test tubes with hot and cold water and touching various parts of the body with these.

Taste.—The tongue is a muscular organ which lies in the mouth cavity and is attached at the base by a fold of mucous membrane. The tongue is covered by mucous membrane which is smooth on its under surface but is rough and irregular on the upper surface on account of the projections called papillæ. These papillæ contain collections of cells called *taste-buds* in which the nerves of taste end.

The tongue is supplied by three nerves, the fifth, ninth and twelfth nerves. The fifth and ninth nerves are sensory,

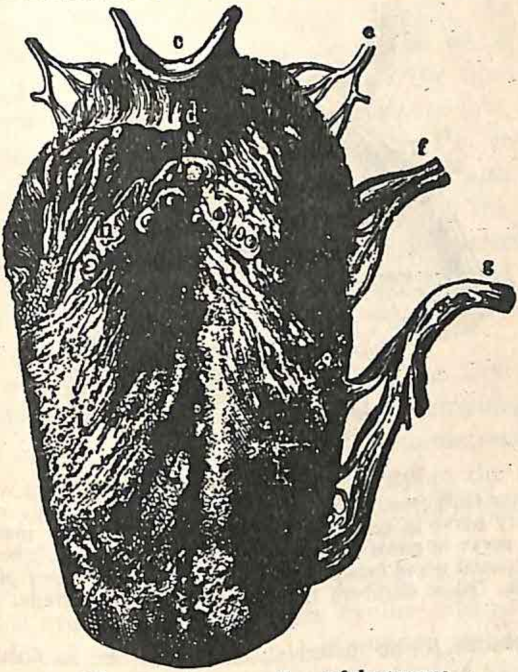

Fig. 79.—*Upper surface of the tongue*

d, back of the tongue connected with *c*, the hyoid bone; *e*, branch of ninth cranial nerve (taste); *f*, branch of twelfth cranial nerve of muscles of the tongue (movement); *g*, branch of fifth cranial nerve (taste); *h*, circumvallate papillæ; *i*, fungiform papillæ; *k*, filiform papilæ.

the former supplying the front and middle portions of the tongue and the latter, the back portion. Both these nerves are nerves of taste. The twelfth cranial nerve is a motor nerve and controls the various movements of the tongue in rolling the food about and in speaking.

The sensation of taste is brought about by the stimulation of the taste-buds by substances in solution, the stimulation being transformed into nervous impulses and conveyed to the brain by the nerve fibres. It is essential that the substance to be tasted should either be in solution or capable of being dissolved in the saliva. This can be illustrated by wiping the tongue dry and putting on it a little bit of salt, when no taste will be felt, till the salt, begins to dissolve. There are only four kinds oftaste, bitter, sweet, salt and acid and they are felt through excitation of different taste-buds. Thus while the tip of the tongue is most sensitive to sweet, the back part is most sensitive to bitter substances. All other tastes are only mixtures of these

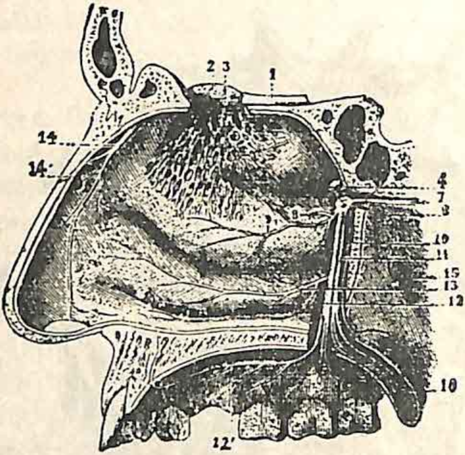

Fig. 80.—*Outer wall of nasal cavity.*

The three turbinated bones are seen covered by mucous membrane, 1, olfactory nerve in cranium; 2, its dilated ends; 3, branches of olfactory nerve in nasal cavity; 5, a nerve ganglion with branches of the fifth cranial nerve below proceeding to the lower part of the nose and palate. Other numbers refer to unimportant details.

four basic tastes. In many of the tastes however the sense of smell is closely associated. The flavours of various substances are mainly due to their odour. That explains the common practice of holding one's nose while taking a nauseous medicine. This is also the reason why a bad cold in the nose prevents the enjoyments of the flavours of various articles we eat.

Smell.—The nose is the organ of smell. The cavity of the nose is lined by mucous membrane which is richly supplied by nerves and blood-vessels. The upper part of each nostril is supplied with branches of the first cranial or the special nerve of smell. The lower part of each nostril serves for breathing. It has nothing to do with the sense of smell. In ordinary quiet breathing when the air passes through the lower part, a smell is notalways detected and to detect very delicate odours one has to 'sniff' the air which brings the odorous particles into more direct contact with the end-organs of smell.

The endings of the olfactory nerve, or nerve of smell, are only excited by molecules of vapours reaching the cells of the olfactory epithelium and this stimulation generates a nervous impulse which is transmitted to the brain. All smells are therefore due to vapours, and substances which do not give off vapours have no smell.

The loss of smell during a bad cold is due to the fact that the mucous membrane gets swollen and prevents the access of air from the lower to the upper part of the nose where the olfactory cells and endings of the olfactory nerves are situated.

Questions for Examinations

1. What do you understand by a Sense-organ? What are the important Sense-organs?
2. Describe the organs of taste.

3. Sketch and describe the nasal cavity. What nerve is concerned with the sense of smell?

CHAPTER XX

THE EYE AND VISION

Protection of the Eyeball.—The eyes are the organs of sight and lie in the bony cavities of the skull called the orbits. Each is like a ball and the second cranial or optic nerve connects it with the brain. In front the eyeball is protected by the *eyelids* which are movable folds of skin and muscle. The inner surface of the eyelids is covered by a thin mucous membrane called the *conjunctiva* which is also reflected on the front of the eyeball. The edges of the eyelids are provided with tiny hairs called *eyelashes*. By the contraction of the muscles of the eyelids they can be closed, the upper eyelid has in addition a muscle which can raise it.

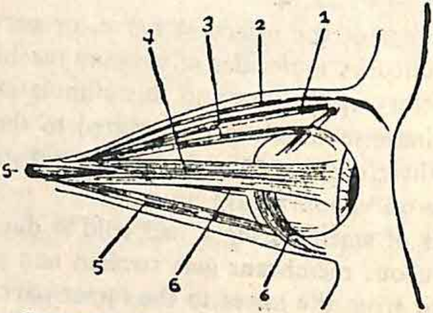

Fig. 81.—*Diagrammatic representation of the muscles of the right orbit.*

1, superior oblique muscle passing over a pulley to its insertion;2, muscle which raises the upper eyelid; 3, superior rectus muscle; 4, external rectus muscle (the internal rectus not seen); 5, inferior rectus muscle; 6, optic nerve; 7, inferior oblique muscle.

The conjunctiva is kept moist by a saltish fluid produced continuously by the *tear gland* situated in the upper and outer part of each orbit. This fluid spreads over the whole of the conjunctiva and after washing the front surface of the eye, collects in the inner angle of each eye and passes through two small holes, into the nasal ducts and is conveyed to the nose. When from any cause such as irritation by vapours or as the result of strong emotion, there is abundance of this secretion and the nasal ducts cannot carry away the fluid, it overflows on to the cheeks as tears.

Movements of the Eyeball.—The eyeball is moved in various directions by means of muscles which are attached to its outer surface. They are six in number, four *straight* and *two oblique*. The four straight or recti muscles come from the back of the orbit and are inserted above, below and on each side of the eyeball turning the front of the eyeball upwards, downwards, outwards and inwards, respectively. The oblique muscles bend in their course. The superior oblique reaching near the front and passing over a pulley turns backwards to be inserted on the outer and back portion of the eyeball and thus turns it obliquely outwards and downwards. The inferior oblique is inserted on the outer and under surface of the eyeball and turns it outwards and upwards.

Separately or in combination these muscles turn the eyeball in various directions. Both the eyes are ordinarily moved together in the same direction, so that the axes of the eyeball remain parallel; when the eyes look at a near object both the eyes are turned inwards. If however there is some defect in the muscles and they are not properly co-ordinated, squint results, and objects are seen double.

The Eyeball.—The eyeball is not quite globular, being less from the front backwards and from above downwards than from side to side. From side to side it is about one inch in diameter. The front portion of the eyeball bulges slightly, being a portion of a smaller sphere. When the eyeball is dissected, its wall is seen to be composed of three coats or layers which enclose two spaces or chambers filled with transparent substances. The three coats from without inwards are—

(*a*) The sclerotic and cornea.
(*b*) The choroid and iris.
(*c*) The retina.

The *sclerotic* or the white of the eye is the thick fibrous coat which covers the posterior five-sixths of the eyeball and is continued in front into the transparent circular portion that bulges forward and is called the cornea. When you look at a person's eye from the front a portion of the sclerotic is seen as the opaque white region surrounding the central circular cornea which is transparent but appears to

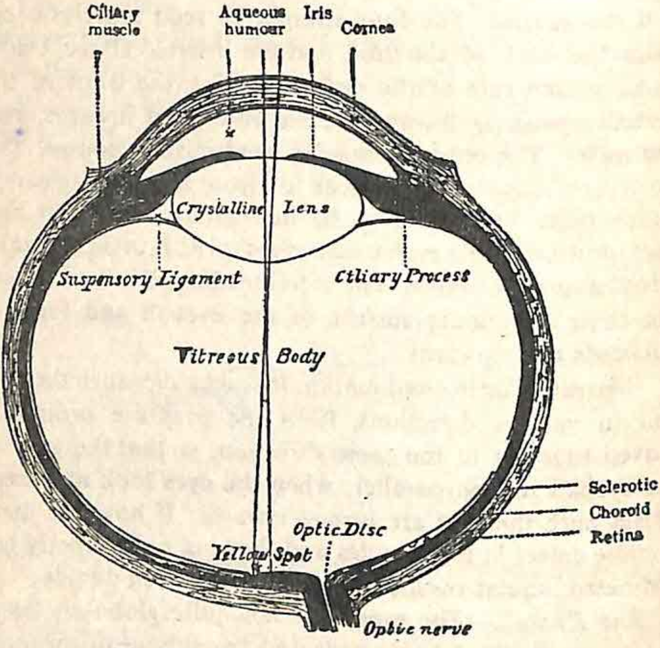

Fig. 82.—*Horizontal section of the left eyeball*
(From Waller's 'Human Physiology'. By permission)

be dark, or brown, or blue according to the colour of the iris lying behind it and shining through it. The sclerotic is pierced behind by the thick cord-like optic nerve, and to its outer sruface are attached the various muscles which move the eyeball in various directions.

The *choroid* is the dark brown membrane lying internal to the sclerotic and loosely attached to it. It consists of connective tissue containing numerous blood-vessels and pigment cells. Its function is to darken the chamber of the eye and prevent reflection of light. Like the sclerotic it is pierced behind by the optic nerve. In front it becomes continuous with the iris, a coloured circular curtain which lies some distance behind the cornea. But just before passing into the iris the inner surface of the choroid is thrown into a number of folds or plaits known as the *ciliary pro-*

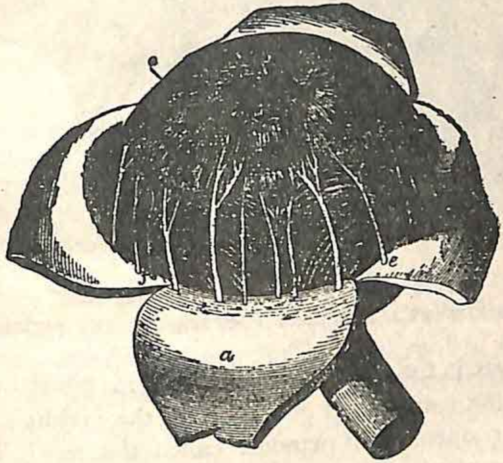

Fig. 83.—*The Choroid and Iris exposed.*
(From Quain's 'Anatomy', By permission.)
The cornea has been removed and flaps of the sclerotic turned back; *a*, portions, of the sclerotic turned back; *b*, ciliary muscle; *c*, iris; *d*, choroid; *e*, one of the ciliary nerves; *f*, blood-vessels.

cesses, and on the outer surface is seen a circular band of muscle, called the *ciliary muscle*. The ciliary muscle arises from the inner surface of the junction of the sclerotic and cornea and passes backwards to be inserted into the outer surface of the junction of choroid and iris. Thus when it contracts it pulls forward the choroid, with the ciliary processes fitting into the capsule of the lens; the capsule thus relaxes its hold on the lens and allows it to become more convex.

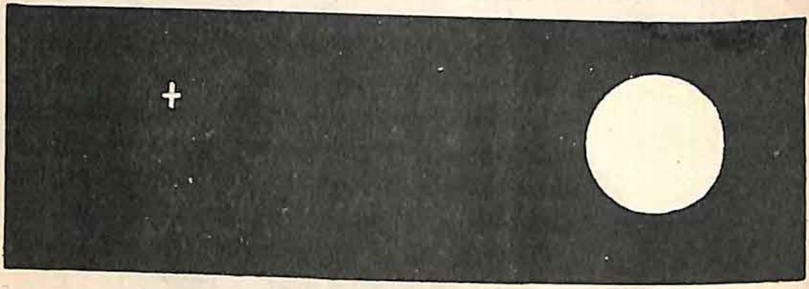

Fig. 84.—*To demonstrate the blind spot.*
(From Starling's 'Principles of Physiology'. By permission.)

The *iris* is the circular dark curtain which is seen through the transparent cornea. In the middle there is a circular opening or window called the *pupil*. The iris contains muscular fibres some of which are arranged circularly and others radially around the pupil. The circular fibres by their contraction narrow the opening of the pupil while the radials dilate the pupil. The iris thus regulates the amount of light that enters the eye and fulfils the same purpose as the diaphragm of a camera or a microscope. Both sets of fibres are involuntary and their action is purely reflex. When the eye is closed or turned away from light the pupil dilates, and when the eye is opened and turned towards light, the pupil is seen to contract.

The iris gives the colour to the eye which differs in different persons and races. It consists of connective tissue containing pigment cells. The back surface of the iris like the choroid is quite dark.

The *retina* lies internal to the choroid to which it is loosely attached. It is an expanded outgrowth of the optic nerve and lines about two-thirds of the interior of the eyeball. The point where the optic nerve enters is called the *blind spot*, as light falling on it does not produce a sensation. Exactly in the centre of the retina, corresponding to the axis of the eye is an area called the *yellow spot*. At this spot vision is most acute.

When sections of the retina are examined under the microscope it is found to consist of numerous layers. Of these the most important is the layer of rods and cones. These are the structures which are sensitive to light and the sensitiveness of any part of the retina depends upon the number of rods and cones present at the spot. At the blind spot these are absent, whilst they are most numerous at the yellow spot, where the vision is most acute. The fibres of the optic nerve convey the visual impressions to the brain. We are not ordinarily aware of the blind spot in the eye, but a simple experiment can demonstrate its existence.

Close the left eye and with the right eye gaze steadily at the cross in figure 84, holding the book upright at about twelve inches from the face. The circle is also seen. Now move the book slowly towards you and at a certain distance the white circle disappears, as its image is now falling on the blind spot. The black background appears to be continuous showing that the gap is unconsciously filled up. On bringing the book closer, the circle is seen again.

The Chamber of the Eye.—The iris stands as a vertical curtain and divides the interior of the eyeball into two cavities or chambers, the smaller *anterior chamber* lying between the iris and cornea and the larger *posterior chamber* lying behind the iris and enclosed by the retina. The anterior chamber is filled with a clear watery, transparent fluid called the *aqueous humour*. The posterior chamber is filled with a transparent jelly-like susbtance enclosed in a membrane and known as the *vitreous humour*, which supports the crystalline lens situated just behind the iris. The aqueous humour, the crystalline lens and the vitreous humour serve as the refractive media of the eye, bending the rays of light entering the eye so as to bring them to a focus on the retina and thus produce a distinct impression.

The *crystalline lens* is perfectly transparent, convex in front and behind, and lies immediately behind the pupil.

Vision.—Before any object can be seen, it is necessary that the rays proceeding from it should be focussed on the retina. In nature, rays proceeding from a near object are invariably divergent, while those proceeding from objects at distances above twenty feet are more or less parallel. Before these divergent or parallel rays can be focussed on the retina, it is obvious that they should undergo some bending or refraction. This change of divergent or parallel rays into convergent rays is brought about by a double convex lens. A double convex lens has both its surfaces convex and so is thickest in the middle and thinnest at the margins.

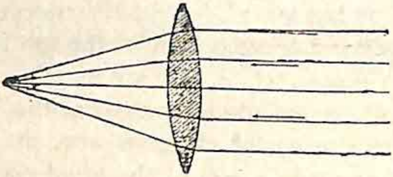

Fig. 85

To demonstrate the formation of images by a convex lens a few simple experiments may be performed:—

(1) Hold a convex lens facing the sun, placing behind it a sheet of paper to act as a screen. Now move the lens

to and from the screen, till a bright spot is formed on it. This is produced by the rays of light converging to a point in passing through the convex lens.

(2) Now light a candle inside a room and put the lens facing the candle flame at a distance of a few feet, holding a screen behind. At a certain distance from the lens an inverted image of the candle is formed on the screen (Fig. 86). Move the lens nearer to or farther from the screen and note the place where the image is clear and brightest. The screen is now said to be placed at the focus of the lens and the distance between the lens and the screen is known as the focal distance of the lens.

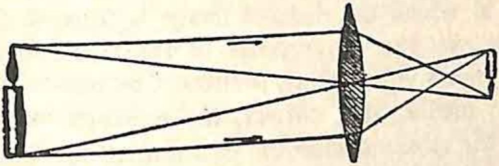

Fig. 86

The formation of an inverted image shows that the rays from the luminous object have crossed each other in passing through the lens. If the candle is brought nearer the lens, the distinct image is formed further behind (Fig. 87) and *vice versa*.

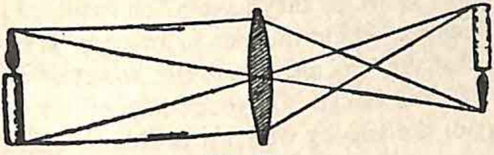

Fig. 87

(3) Next take a lens with more convex surfaces and repeat the above experiment. We find that to get a distinct image on the screen the distance between the lens and the screen is much less because there is now greater bend-

ing of the ray. By repeating the experiment with several lenses we find that the more convex the lens, the shorter the distance at which a distinct image is produced.

Thus we have learnt that (1) a convex lens forms an inverted image of an object, (2) the nearer the object is to the lens, the greater the distance between the lens and the screen, and (3), the more convex the lens, the shorter the distance at which the distinct image is formed.

In the eye, the convergence of the rays coming from various objects you look at, is effected by means of various refractive media, viz., cornea, the aqueous humour, the lens and the vitreous humour. In a normal eye, they enable the rays of light coming from various objects to form a clear image on the retina. These images produce a visual sensation which is conveyed through the optic nerve to the brain where perception or conscious vision takes place. Sight would be interfered with if there is some defect in the refractive media, the retina, optic nerve, or the part of the brain which receives the visual sensations.

Power of Seeing Objects at Different Distances.—The objects looked at are at varying distances from the eye, while the point at which they have to be focussed is always the same distance behind the lens in any eye. It is obvious, therefore, that the lens must have the power of varying its convexity if clear images are to be formed on the retina. The power of the lens by which it is able to form distinct images on the retina of both distant and near objects is called *accommodation*. The normal eye is so constructed that rays coming from a distance (which are parallel rays for all practical purposes) are focussed on the retina without any accommodation. But for distances less than twenty feet effort of accommodation is needed. As the distance between the retina and the lens of the eye is fixed and unalterable, the lens increases in convexity when looking at near objects. This is brought about by the action of the ciliary muscle pulling forward the choroid and the ciliary processes, thus loosening their hold on the suspensory ligament of the lens, and enabling the lens to bulge forwards. The nearer the object looked at, the greater will be the contraction of the ciliary muscle and the consequent greater convexity of the lens. Too much near work such as reading and writing, by throwing too much strain on the ciliary muscle, tends to weaken the muscle and ultimately causes myopia or short-sight.

Binocular Vision.—In looking at an object with both eyes images are formed on both the retinas and for an object to appear single, it is necessary that the images should be focussed on the corresponding positions of the two retinas. The seat of clearest vision is the yellow spot and therefore in looking at a near object, the eyes must converge if the object is to be seen single, so that the image may be formed on the yellow spot in each eye.

This is effected by means of the muscles of both eyes always working in co-operation. Convergence and accommodation always take place together in the two eyes. By looking at objects with both eyes we get a better idea of the form of the object and their respective position in space. This principle is imitated in looking at pictures through the stereoscope, when the objects represented in the picture, stand out in relief and a vivid idea of the panorama is conveyed.

Some Visual Sensations.—The retina gets easily tired. Thus if we look at a bright light for some time and then turn and look at a white paper we see on it a dark spot. It is because the portion of the retina on which bright light had been falling has become tired and insensible. The retina is able to retain the impressions made upon it for about 1/8 of a second after the object looked at has been removed. If a succession of moving pictures is shown on a screen at such a speed that the image of a new one is formed while the image of the last has not faded, objects will appear to show life-like movements on the screen. This is the principle of the cinematograph. Many other examples of daily occurrence can be easily recalled. Thus a lighted stick moving rapidly round appears as a lighted circle and an ascending rocket produces a trail of light.

White light is composed of seven colours, violet, indigo, blue, green, yellow, orange and red, the colours composing the rainbow. This can be demonstrated by passing a ray of light through a prism which splits it into its seven component colours and produces a *Spectrum.*

Some people are 'Colour blind' that is to say are incapable of recognising differences between certain colours. The defect is due to some defect in the retina.

Defects of vision.—A normal eye, as already stated, is so constructed that parallel rays, and rays coming from objects beyond twenty feet are parallel for all practical purposes, are focussed on the retina without any effort of accommodation.

If, as sometimes happens, the eyeball is comparatively too short so that rays coming from distant objects are focussed behind the retina and produce indistinct vision, and bringing the object nearer the eye makes the image still more indistinct, the person cannot see objects distinctly at any distance unless accommodation is used. He suffers from headaches even when not putting any strain on the eyes. While reading he tries to keep the book as far away as possible. He is consequently said to be suffering from *long sight* or *hypermetropia.* He needs converging or convex glasses to be used constantly. It must however be remembered that glasses should be worn as ordered after examination by a qualified doctor. This defect is usually from birth.

If however the eyeball is too long and the parallel rays coming from a distance are not focussed on the retina but in front of it, the image formed is indistinct. The person therefore has to bring the object nearer to his eyes or reach

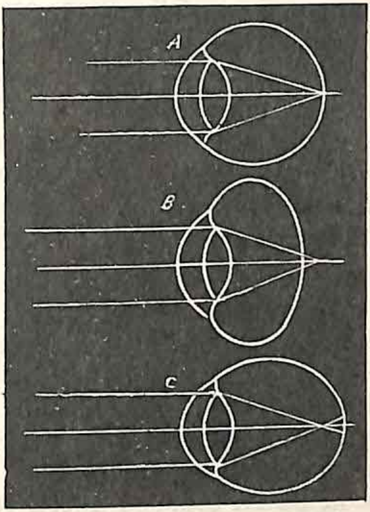

Fig. 88—*Diagram of course taken by parallel rays on entering the eye.*

(From Starling's 'Principles of Physiology'. By permission.)

A, normal eye, parallel rays focussed on the retina.
B, hypermetropic or long-sighted eye, parallel rays focussed behind the retina.
C, myopic or short-sighted eye, parallel rays focussed in front of the retina.

closer to it in order to see distinctly. He is therefore called *short-sighted* or *myopic*. Such a person needs suitable concave glasses to see things properly, as such lenses will scatter the rays and they will be focussed on the retina. This defect is usually acquired from reading fine print or doing other fine work at an early age, reading and sewing in poor light, and sitting in faulty position.

There is one more defective condition of the eye which is fairly common. It is called *astigmatism*. In this the curvature of the cornea is not uniform in all its diameters, so that some portions of the image are focussed on the retina while other portions are focussed either behind or in front of it. Such a person while looking at a cross sees one or the other of the arms indistinctly. In some cases the eye may be myopic in one meridian and hypermetropic in the other. The person needs compound glasses, that is lenses which are not regular in all the diameters. It is obvious that such glasses have to be worn constantly. This defect may be congenital or acquired.

Questions for Examinations

1. Sketch and describe the parts of the human eye.
2. Explain the process of vision. What is a 'blind spot' and how will you illustrate it?
3. What are the common defects of eyesight and how may they be corrected?
4. How do you explain the phenomenon of binocular vision?
5. What precautions are necessary to avoid weakness of eyesight?
6. What do you understand by the terms, myopia, hypermetropia and astigmatism?

CHAPTER XXI

THE EAR AND HEARING

The Organ of Hearing.—The ears are organs by means of which sound waves are collected and converted into a nervous impulse to be transmitted to the brain. The sound waves are collected by the outer expanded portion popularly known as the ear, which is in reality only the *external ear*. This leads into a narrow passage called the *auditory canal* which is closed on the inner side by a thin circular membrane called the drum of the ear or the *tympanic membrane*. The tympanic membrane separates the outer from the middle ear. The *middle ear* or tympanum is a small cavity in the temporal bone, containing a chain of three small bones which connect the tympanic membrane with the internal ear. The *internal ear* consists of a very complex apparatus situated in the inner projecting portion of the temporal bone, in the interior of which there are special sensory cells to which the fibres of the auditory nerve are distributed.

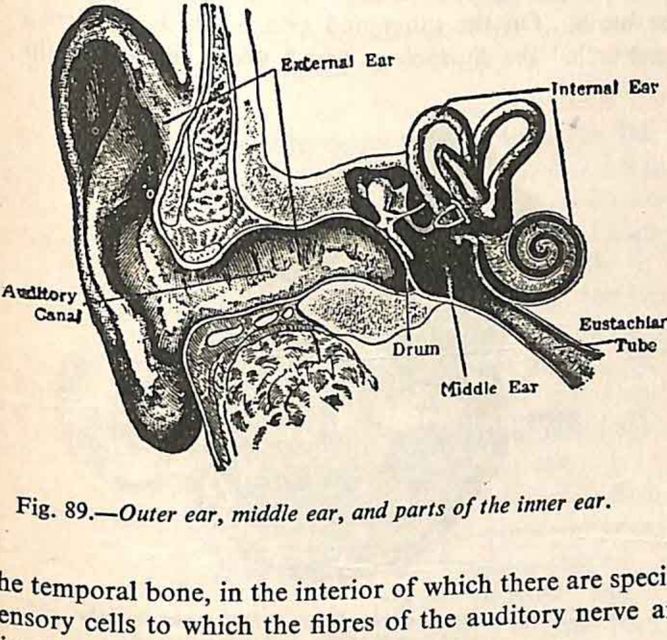

Fig. 89.—*Outer ear, middle ear, and parts of the inner ear.*

The External Ear.—The external ear consists of an irregular plate of cartilage covered with skin, leading into the auditory canal. The canal is about 1¼ inch long. It leads obliquely inwards and forwards to the drum, and is lined with a thin layer of skin which has hair and contains glands secreting the ear wax. The hair and the wax serve to catch the dust which might otherwise irritate the tympanic membrane.

The Middle Ear.—It is an irregular cavity situated in the temporal bone. It is lined by mucous membrane and filled with air. It is separated from the external ear by the circular tympanic membrane, and from the brain by the piece of bone enclosing it. Thus it is that any discharge from the ear is a serious thing, as it may lead to an abscess in the brain. On the inner and under side is a narrow channel called the *Eustachian tube*,* which leads into the pharynx. In this way the cavity of the middle ear communicates with the air outside, and the pressure on the two sides of the drum is equalized. In case of a sudden

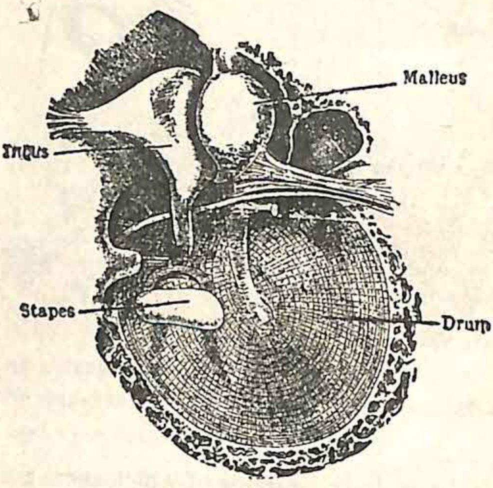

Fig. 90.—*Inner aspect of the drum of the left ear, and the small bones of the middle ear.*
(From Quain's 'Anatomy'. By permission.)

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*Named after an Italian anatomist, Eustachius, who lived in the sixteenth century.

loud noise air is allowed to escape into the pharynx, thus preventing rupture of the membrane. This tube is also the channel through which inflammation may travel from the throat to the middle ear, an occurrence fairly common in children. Behind, the cavity of the middle ear communicates with small spaces in the temporal bone. In cases of discharging ears there is always a danger of pus infecting these spaces causing an abscess which if not opened in time may lead to an abscess of the brain and cause death. In the inner wall of the middle ear there are two small openings closed by membrane—one, oval in shape and the other, round.

Extending from the tympanic membrane to the inner wall of the middle ear is a chain of three small bones by means of which vibrations received by the drum are conveyed to the internal air. They are named the *malleus* or hammer, the *incus* or anvil and *stapes* or the stirrup. The malleus is attached to the drum of the ear, while the footplate of the stapes fits into the oval window leading to the inner ear.

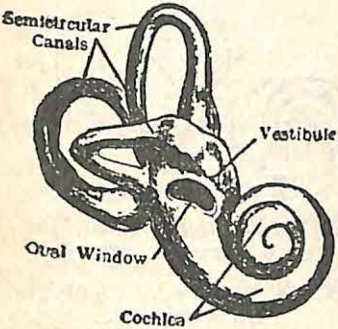

Fig. 91.—*A bony labyrinth removed from the temporal bone in which it lies.*
(2-1/2 times the natural size.)
(From Quain's 'Anatomy'
By permission.)

The Internal Ear.—The internal ear is the complicated irregular-shaped apparatus situated inside the pyramidal internal portion of the temporal bone, and on account of its complicated form is known as the *labyrinth*. Inside the *bony labyrinth* is contained a closed membranous sac of the same form known as the *membranous labyrinth*. The membranous labyrinth contains a clear fluid calledt he *endolymph*.

The labyrinth is the essential part of the organ of hearing and contains the termination of the eight cranial or the *auditory* nerve. It consists of three parts, (1) the *vestibule*, (2) the *cochlea* and (3) the *semi-circular canals*.

The *vestibule* is the central chamber which communicates with the cochlea in front and the semi-circular canals behind. In its wall is the oval window into which the plate of the stapes is inserted.

The *cochlea* is a spiral structure situated below and in front of the vestibule, resembling the shell of a tiny snail. In the membranous cochlea are found the terminations of the auditory nerve.

The *semi-circular canals* spring from the upper and back part of the vestibule. They are three in number placed in different planes, at right angles to each other, and communicate with the vestibule by five openings, as two of them unite before opening into the vestibule. At one end of each canal is a swollen portion, to the interior of which fibres of a branch of the auditory nerve are distributed. The semi-circular canals are concerned with keeping the equilibrium of the body and make us aware of our position and movements in different directions. The fibres of the auditory nerve arising from the semi-circular canals do not go to the auditory centre of the brain but have been traced to the cerebellum which is concerned with the balancing

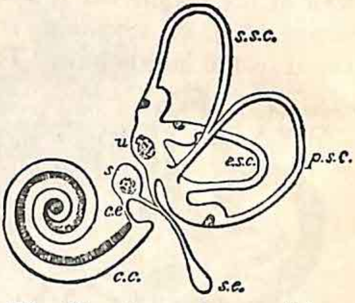

Fig. 92.—*A membranous labyrinth removed out of a bony labyrinth.*
(From Quain's 'Anatomy,' By permission.)
u, *s*, and *s*, *e* parts of the vestibule; *s. s. c.*, *p. s. c.*, and *e. s. e.*, the three semi-circular canals; *c.c.*, uniting canals; *c.e.*, cochlea. The shaded areas indicate the parts to which branches of the auditory nerve are distributed.

of the body. Disease of the cerebellum or semi-circular canals gives rise to dizziness.

Transmission of waves of sound to the end organ of hearing.—Everybody making a sound is vibrating and imparting these vibrations to the air, causing waves to be propagated in all directions. These sound waves travel in the air at the rate of 1,100 feet per second, and reaching the external ear pass through the auditory canal and strike against the tympanic membrane thus setting it into vibrations. These vibrations are transmitted to the malleus which is attached to the inner side of the drum, and this sets the incus and the stapes into corresponding vibrations. The foot-plate of the stapes being inserted into the oval window, produces vibrations in the fluids inside and outside the membranous labyrinth. These vibrations of the fluid then excite the terminations of the auditory nerve and produce a nervous impulse which on reaching the brain gives the sensation of sound.

Deafness.—It is obvious that deafness may be due to various causes. It may be due to blocking of the auditory canal by ear-wax, or the rupture of the drum by anything pushed into it, or as the result of disease of the middle ear. Occasionally blocking of the Eustachian tube from inflammation in the throat produces a defect in hearing. Lastly, disease of the inner ear, auditory nerve, or the hearing centre in the brain may give rise to it.

Questions for Examinations

1. Describe the structure of the ear, and explain the phenomenon of hearing.
2. What are the various causes of deafness?

CHAPTER XXII

THE LARYNX AND VOICE

The Larynx.—The larynx or the organ of voice is the upper modified portion of the trachea. Its walls consist mainly of cartilages bound together by muscles and ligaments. The interior of the organ is lined with mucous membrane continuous with that of the mouth above and the trachea below.

The cartilages forming the larynx are four in number, the thyroid, the cricoid, and the two arytenoid cartilages. The epiglottis and the hyoid bone though not strictly speaking included in the larynx, are closely associated with it and may conveniently be described here.

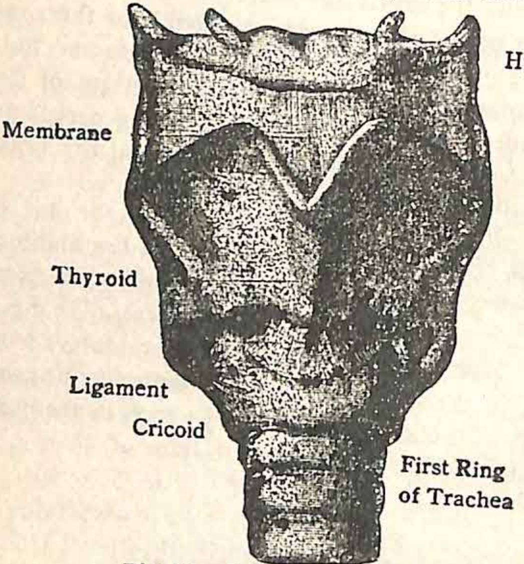

Fig. 93.—*Front view of the Larynx.*
(From Quain's 'Anatomy'. By permission.)

The *thyroid* forms the greater part of the front and sides of the larynx, the prominent ridge of which is popularly known as Adam's apple. It is incomplete behind, the space between the two wings being filled up by a membrane. It is connected above with the hyoid by a membrane and it articulates below on each side with the cricoid cartilage.

The *cricoid* cartilage lies below the thyroid and is the only complete ring in the windpipe. It is shaped like a signet ring, the broad part of which lies behind, while the front part is narrow. The space between it and the thyroid is filled by a membrane. On the upper part of the broad portion behind rest, on either side, the arytenoid cartilages.

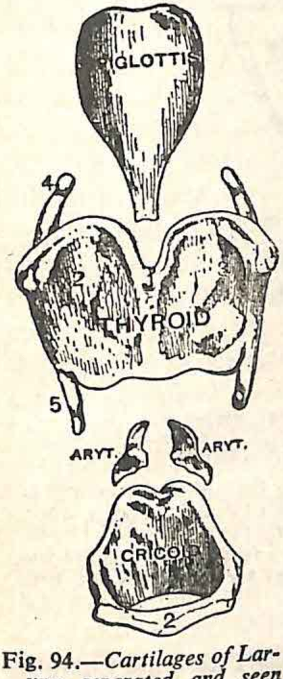

Fig. 94.—*Cartilages of Larynx separated and seen from before.*

The arytenoids are two small pyramid-shaped cartilages lying one on either side, on the top of the posterior broad portion of the cricoid cartilage, and forming moveable joints with it. Stretching between the arytenoid cartilages and the back surface of the thyroid cartilage are two elastic fibrous bands covered over by mucous membrane. These are the vocal cords. They are attached close together so that when they are stretched, their edges are brought nearly parallel and only a small chink is left for the air to pass through. Above the vocal cords are two other folds of tissue situated one on each side, called the false vocal cords, which take part in the production of voice.

The *epiglottis* is a leaf-like piece of cartilage the lower and narrow part of which is attached to the thyroid cartilage. It acts as a lid closing the larynx during the act of swallowing, thus preventing food and drink from getting into the trachea. During ordinary respiration the epiglottis remains erect.

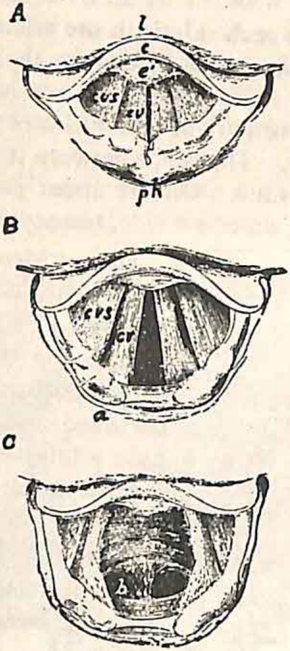

Fig. 95.—*Three views of the larnx during life.*
(From Quain's 'Anatomy'. By permission.)

As seen by looking down the throat by the aid of the instrument called laryngoscope. A, during the singing of a high note; B, during quiet breathing; C, while taking a very deep breath.

cv, vocal cords; *cvs*, false vocal cords; *tr*, front wall of the trachea; *b*, commencement of the two bronchii, as seen through the wide passage.

The *hyoid* bone is a small U-shaped bone lying above the thyroid cartilage at the base of the tongue, with its convexity directed forwards. It does not articulate with any other bone but is suspended by ligaments from the base of the skull. The bone gives attachment to many of the muscles of the tongue and the larynx.

The nervous supply to the larynx is the vagus, which is both motor to the muscles and sensory to its mucous membrane.

Voice and Speech.—As already stated, sound is produced by regular movements of vibrating bodies. Voice is the sound produced by the vibrations of the vocal cords. During ordinary breathing vocal cords are relaxed, the opening of the glottis is wide and the air can pass through it freely (Fig. 95B). When we speak or sing the vocal cords are tightened by means of the muscles attached to the cartilages and the glottis is narrowed into a chink (Fig. 95 A). The outrushing blast of air thus sets the cords into vibration, producing sound.

The pitch of the note depends upon the number of vibrations per minute and these depend upon the tension and length of the cord. The greater the tension or shorter the cord, the higher is the pitch of the sound produced because the number of vibrations per minute is increased. This can be illustrated by means of a wire or string stretched between the points as in a *sitar*.

The quality of the voice depends upon various conditions such as the shape of the mouth, nose and pharynx, the position of the tongue, etc., and is peculiar to each individual. The larynx is exactly alike in boys and girls, but on reaching the age of youth, the larynx of the male rapidly increases in size, causing a corresponding increase in the length of the vocal cords and consequent change in the pitch of the voice.

Speech is voice broken up into words by movements of the tongue against the cheeks, lips and teeth. Whispering is speech without sound as there is no movement of the vocal cords. In it the air current is simply moulded into speech by movements of the tongue and lips.

Questions for Examinations

1. Describe the Larynx, and the cartilages that go to form its walls.
2. Explain the production of voice.

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